Earthquake and Tsunami Hazards :

by

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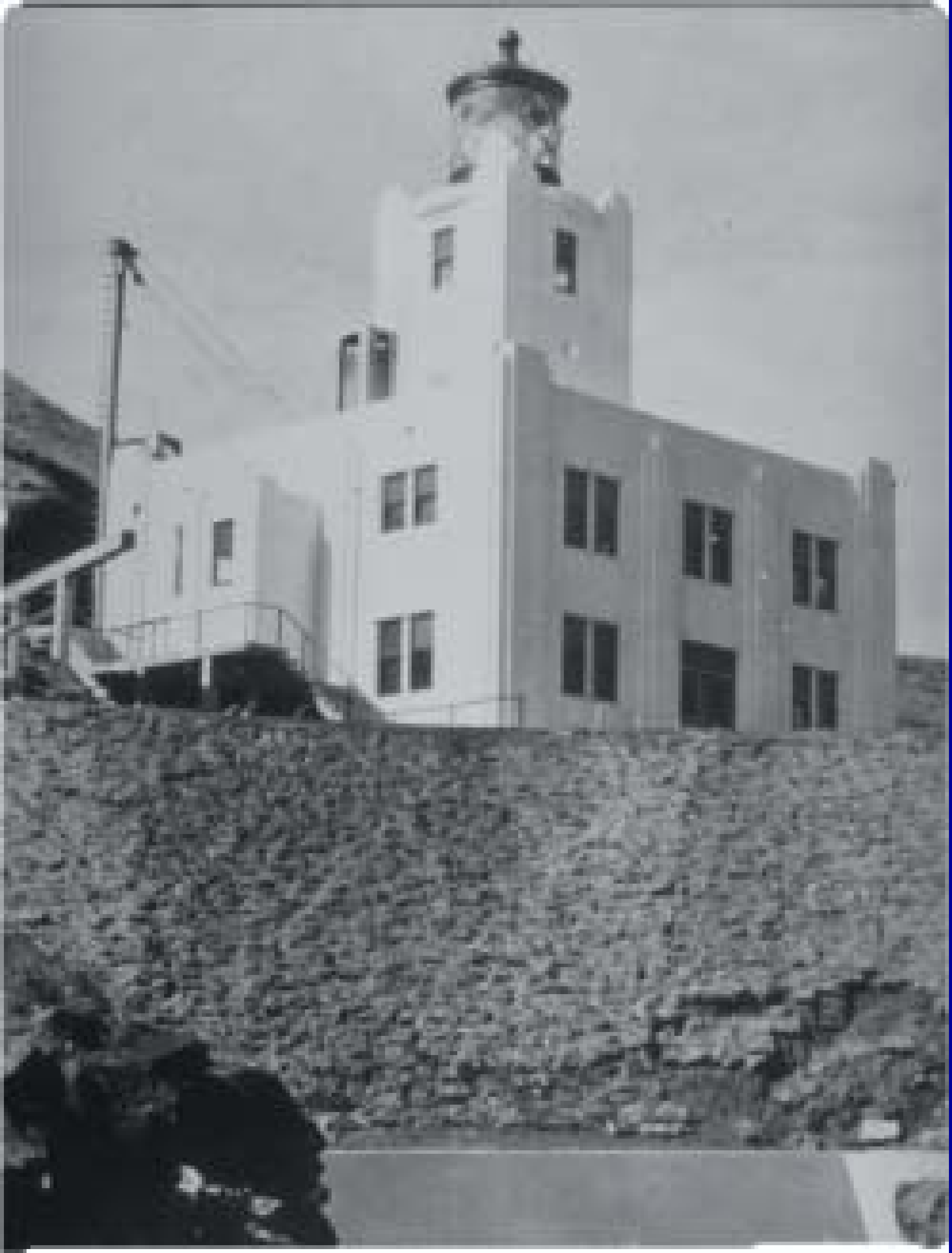
Division of Geology and Earth Resources

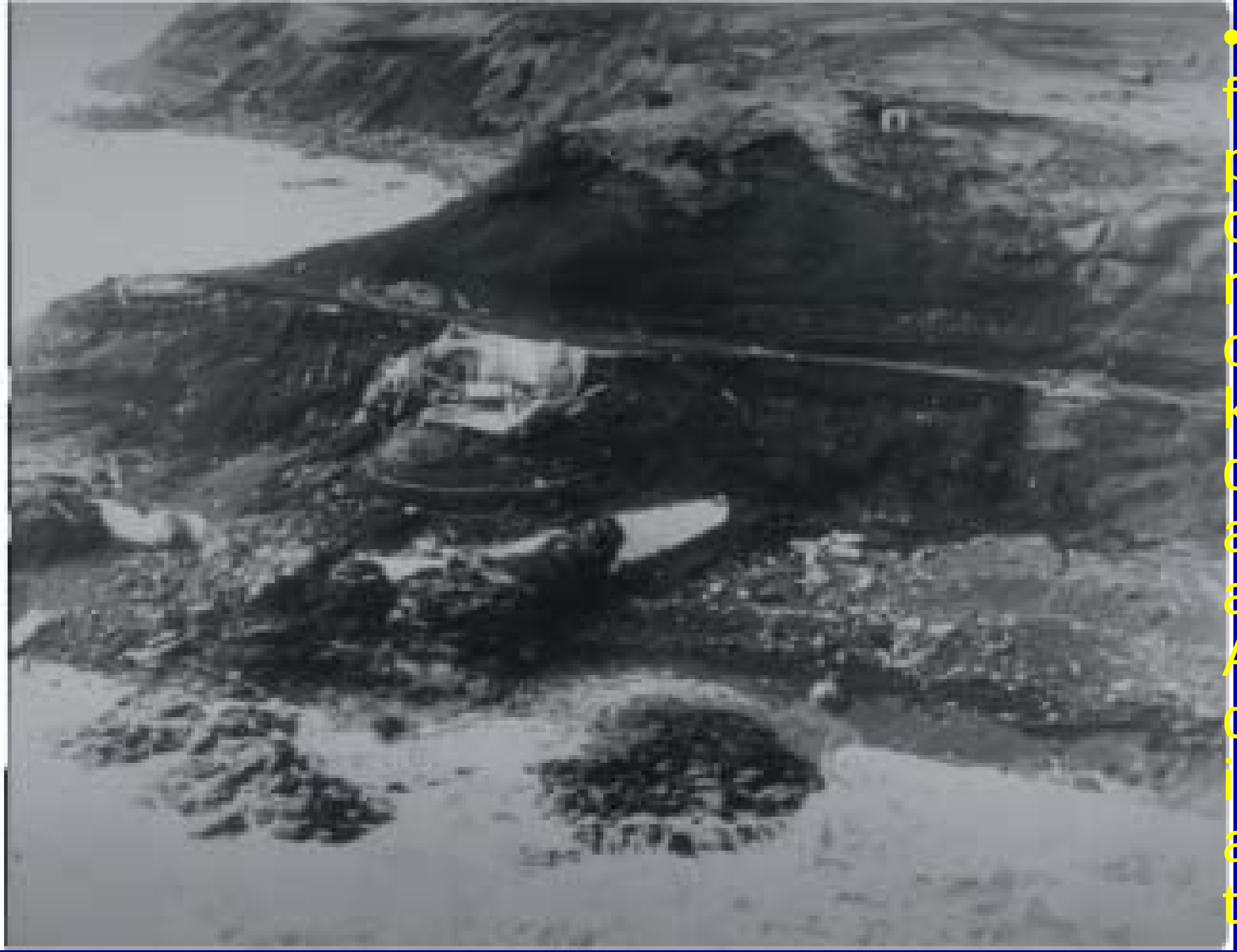
Communications Academy

April 16, 2011

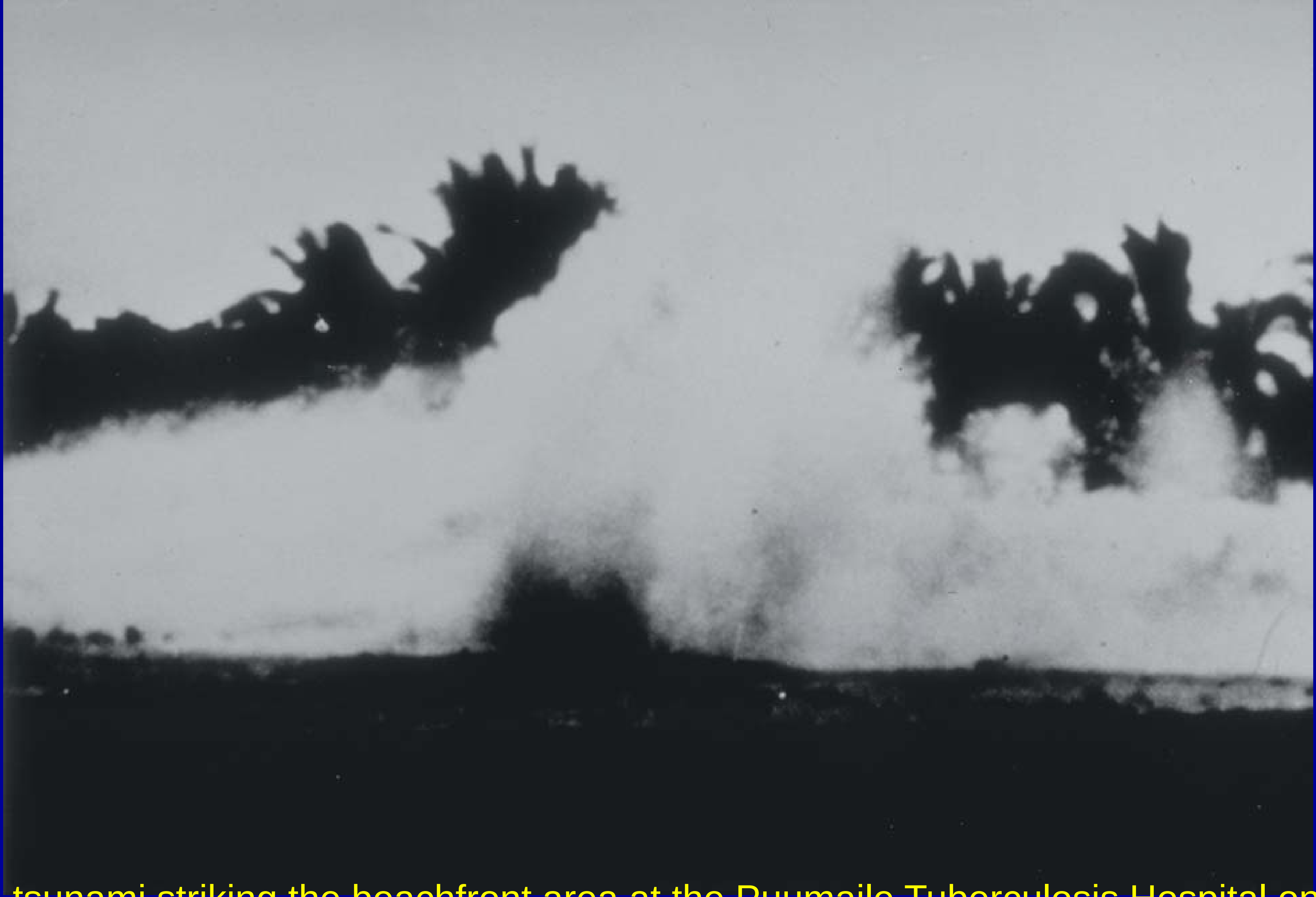
WASHINGTON STATE DEPARTMENT OF
Natural Resources



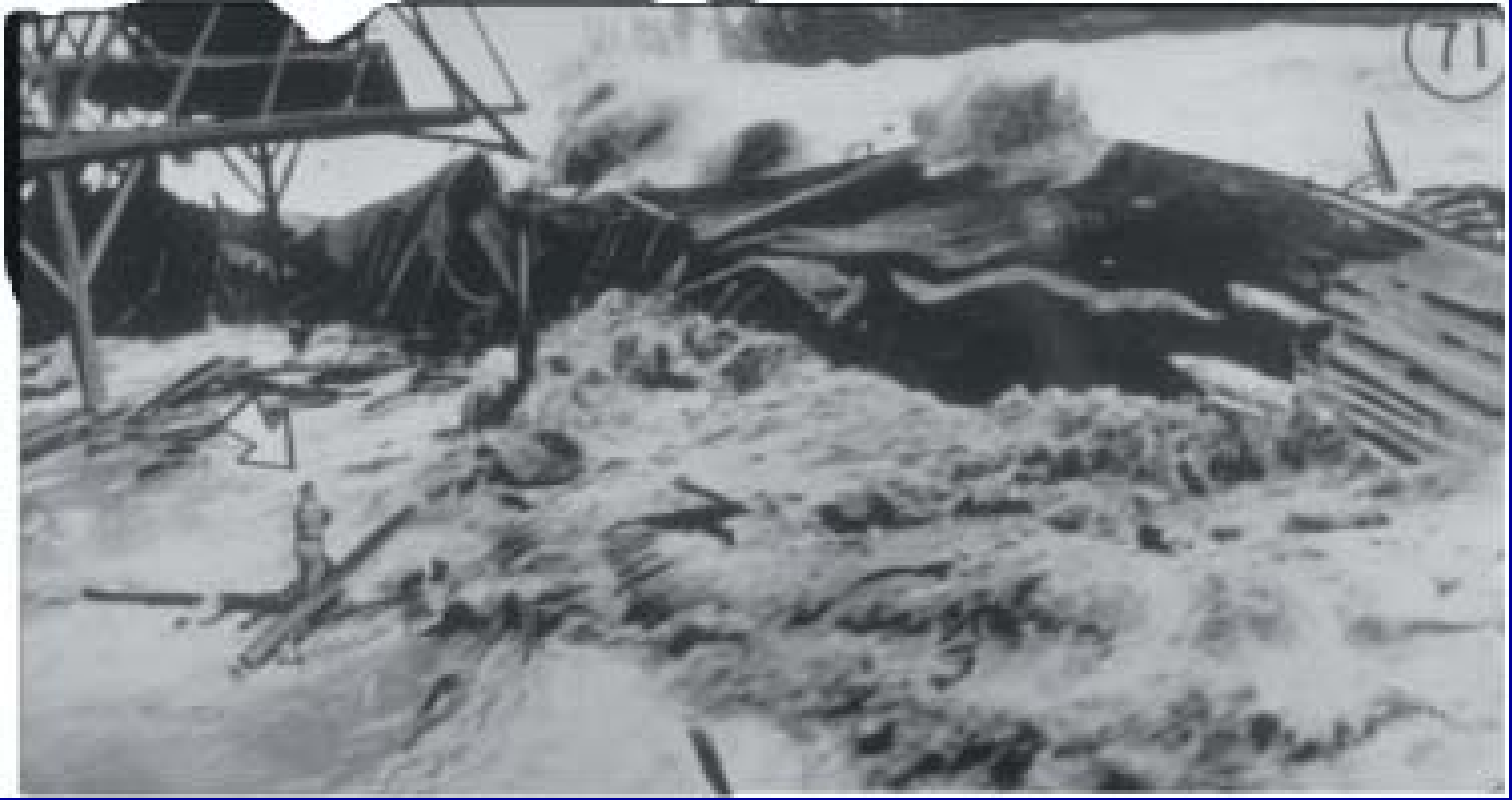
- On April 1, 1946, a magnitude 8.0 (Mw) earthquake with the source in the Aleutian Islands to the south of Unimak Island generated a tsunami that destroyed this five-story lighthouse, located 9.8 m above sea level.



- Only the foundation and part of the concrete sea wall remained. All five occupants were killed. The waves deposited debris as high as 35 m above the sea. Although little damage occurred in Alaska, except at Scotch Cap, the tsunami was one of the most destructive ever to occur in the Hawaiian Islands. Photo credit: U.S. Coast Guard



- 1946 tsunami striking the beachfront area at the Puumaile Tuberculosis Hospital on the Island of Hawaii, about 3,800 km from the generating area. In this area east of Hilo, Hawaii, waves were 6.1 m high overtopping the breakwater and causing minor flooding at the hospital. These catastrophic waves engulfed the Hawaiian Islands suddenly and unexpectedly. The maximum rise of water was almost 8 m in Hilo and as much as 12 m in other areas on the island of Hawaii. Photo credit: Mrs. Harry A. Simms, Sr.



- Tsunami breaking over Pier No. 1 in Hilo Harbor, Hawaii. The man in the foreground was one of the 159 fatalities in the Hawaiian Islands from the tsunami. The photo was taken from the Brigham Victory. The ship was caught by the waves and tossed about but was able to use its own power to avoid the reefs and get past the breakwater to the open sea.

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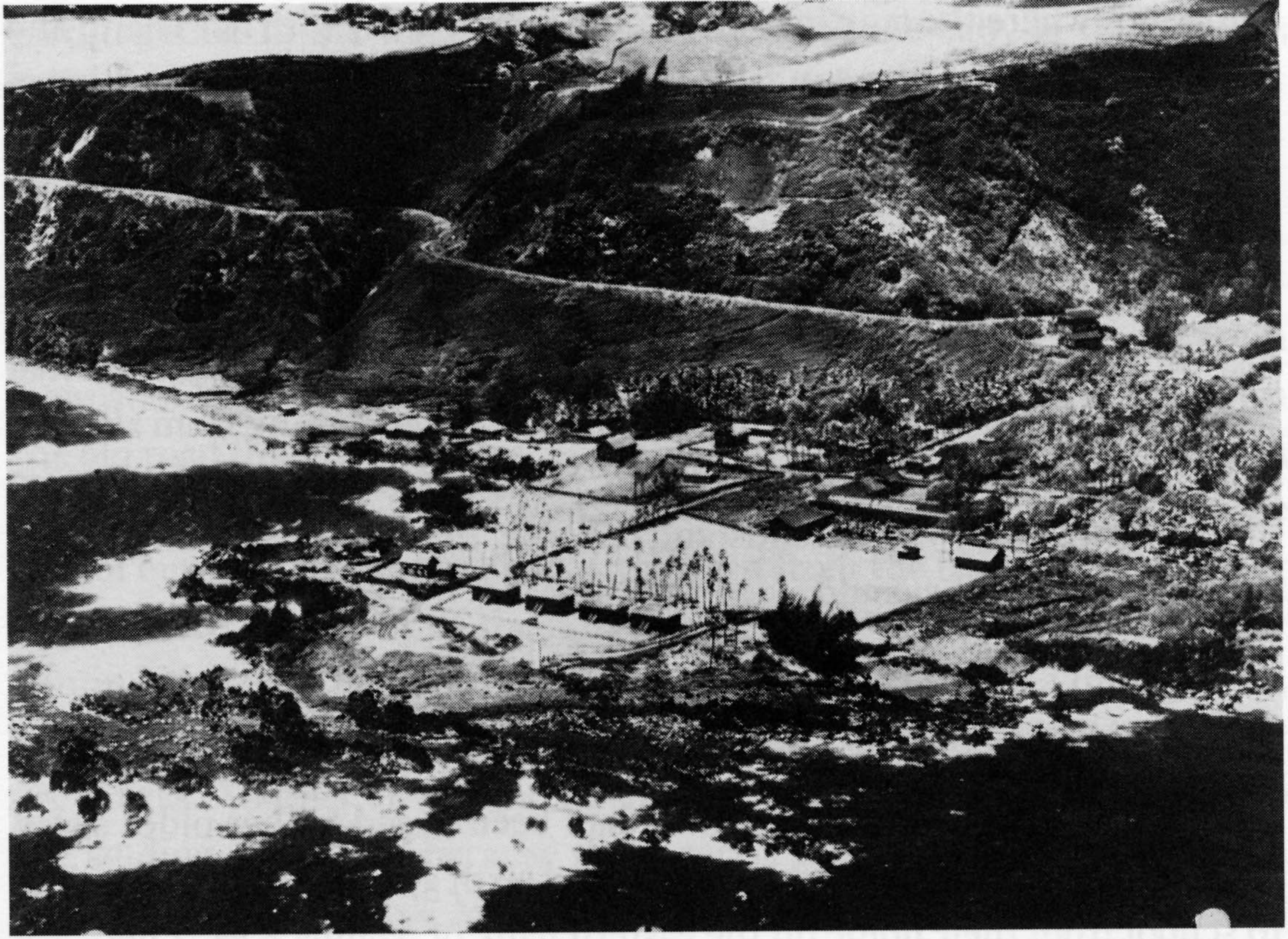
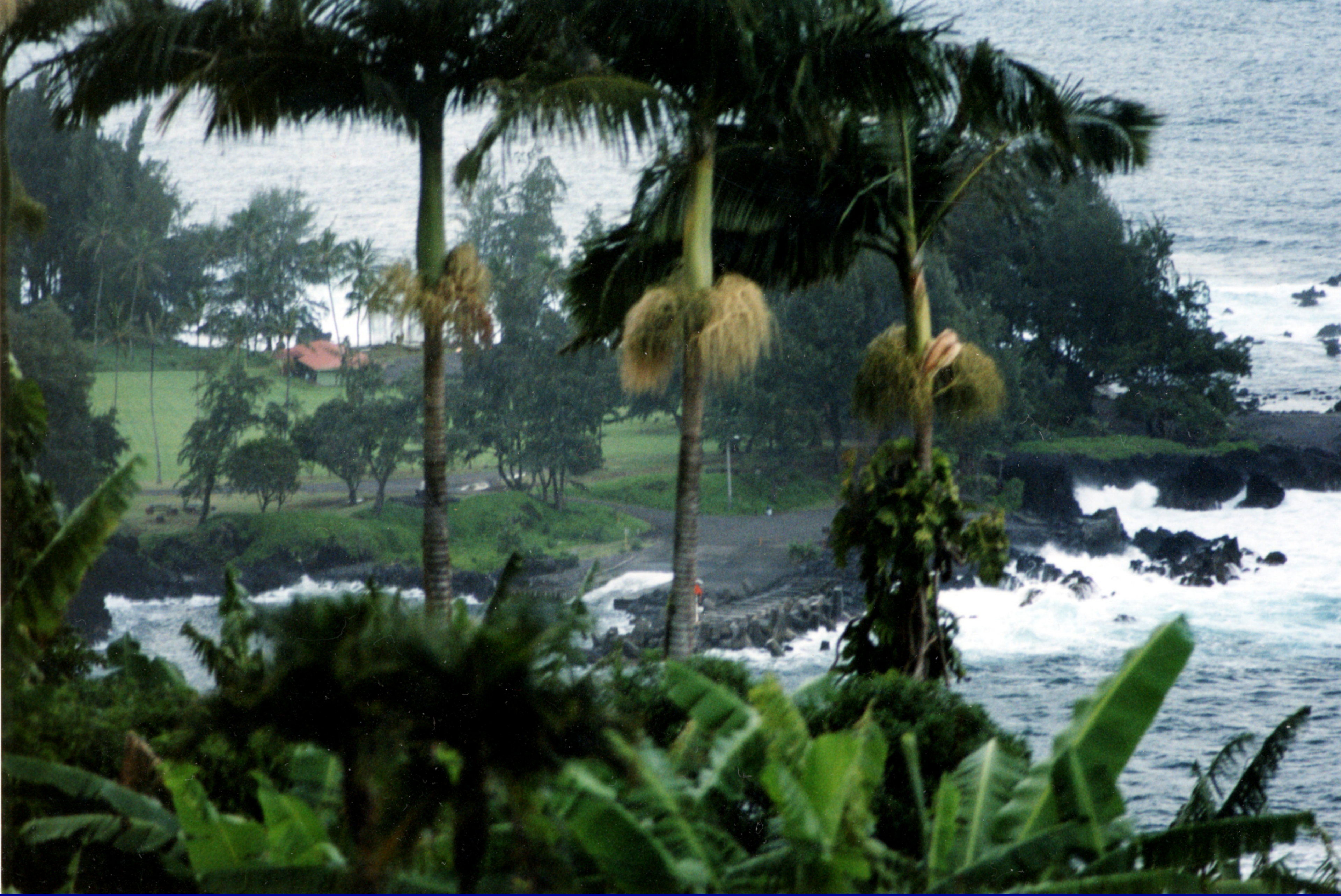


Figure 1.5 Laupāhoehoe Point prior to the tsunami of April 1, 1946. Note the playing fields and cottages nearest the ocean.



The school children noted that the water had receded

- Many went down to the shore to watch

Across what had been the playing fields is the monument to the victims

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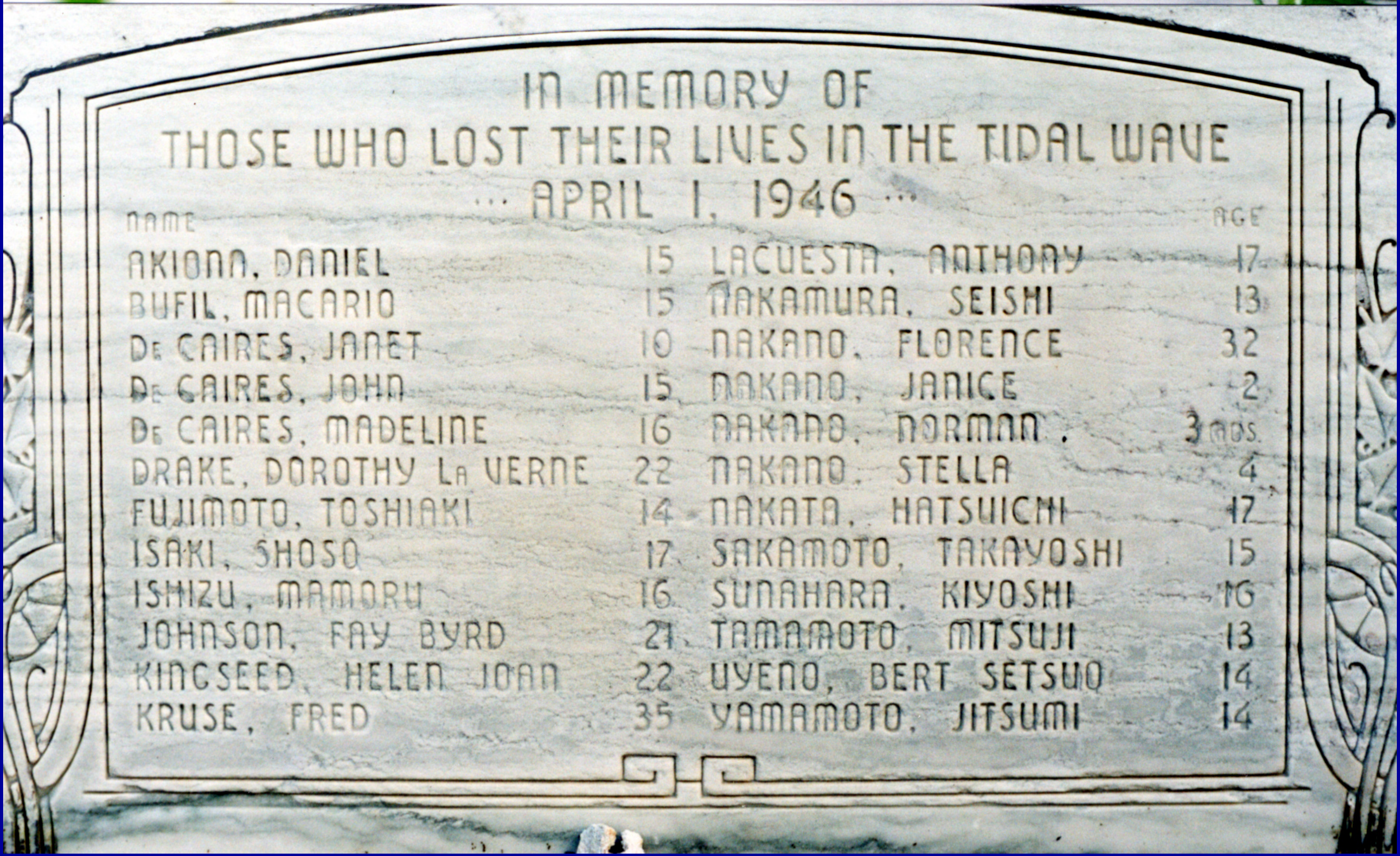

IN MEMORY OF
THOSE WHO LOST THEIR LIVES IN THE TIDAL WAVE
... APRIL 1, 1946 ...

NAME			AGE
AKIONA, DANIEL	15	LACUESTA, ANTHONY	17
BUFIL, MACARIO	15	NAKAMURA, SEISHI	13
De CAIRES, JANET	10	NAKANO, FLORENCE	32
De CAIRES, JOHN	15	NAKANO, JANICE	2
De CAIRES, MADELINE	16	NAKANO, NORMAN.	3 MOS.
DRAKE, DOROTHY La VERNE	22	NAKANO, STELLA	4
FUJIMOTO, TOSHIAKI	14	NAKATA, HATSUICHI	17
ISAKI, SHOSO	17	SAKAMOTO, TAKAYOSHI	15
ISHIZU, MAMORU	16	SUNAHARA, KIYOSHI	16
JOHNSON, FAY BYRD	21	TAMAMOTO, MITSUJI	13
KINGSEED, HELEN JOAN	22	UYENO, BERT SETSUO	14
KRUSE, FRED	35	YAMAMOTO, JITSUMI	14

- At least 24 people were killed here, many of whom were children playing by the waterfront. The tragedy of the 1946 tsunami prompted the U.S. Coast and Geodetic Survey to establish the Tsunami Warning System

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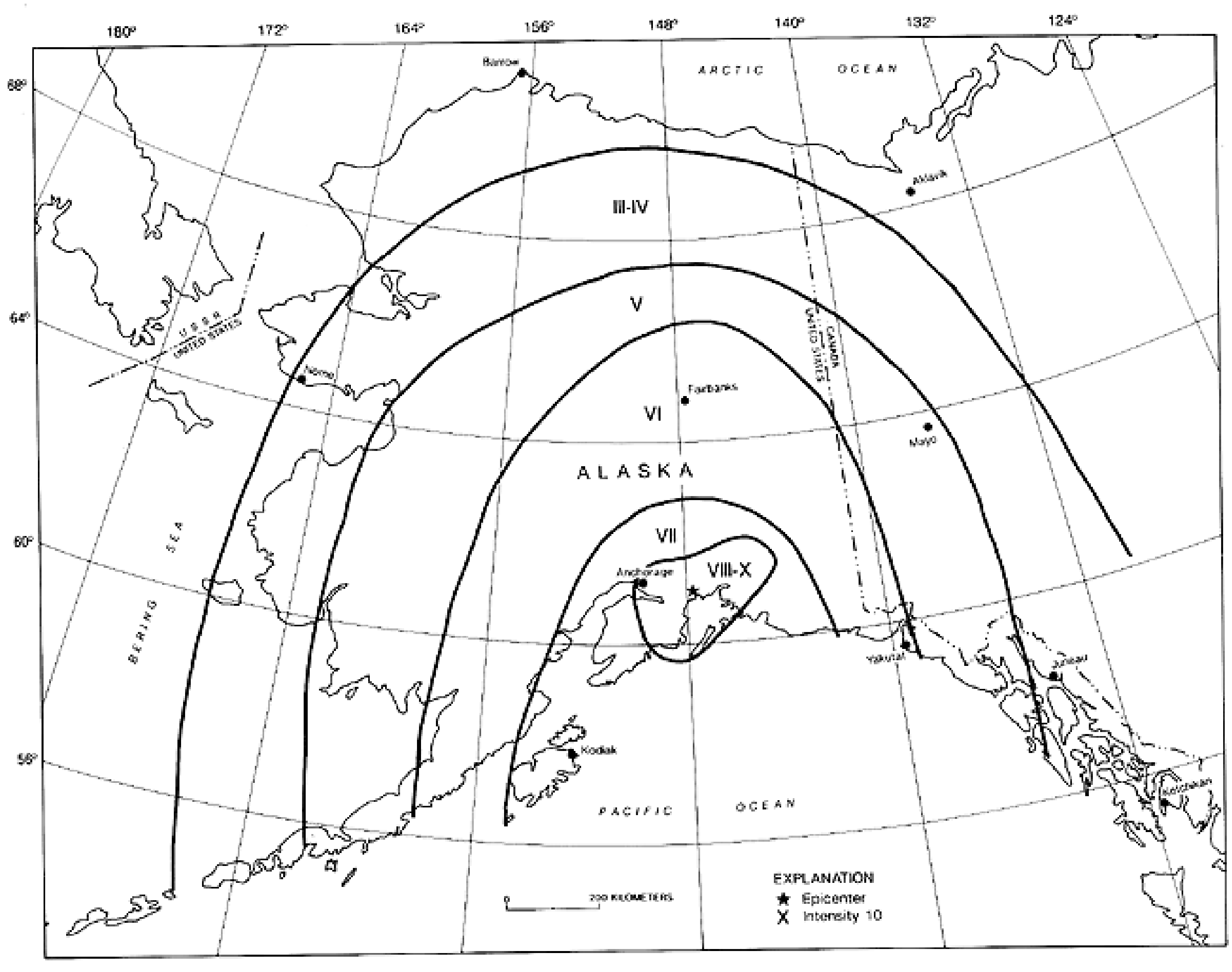
Abridged from Seismicity of the United States, 1568-1989 (Revised), by Carl W. Stover and Jerry L. Coffman, U.S. Geological Survey Professional Paper 1527, United States Government Printing Office, Washington: 1993.



Prince William Sound, Alaska
1964 March 28 03:36:14 UTC (March 27 local) Magnitude 9.2

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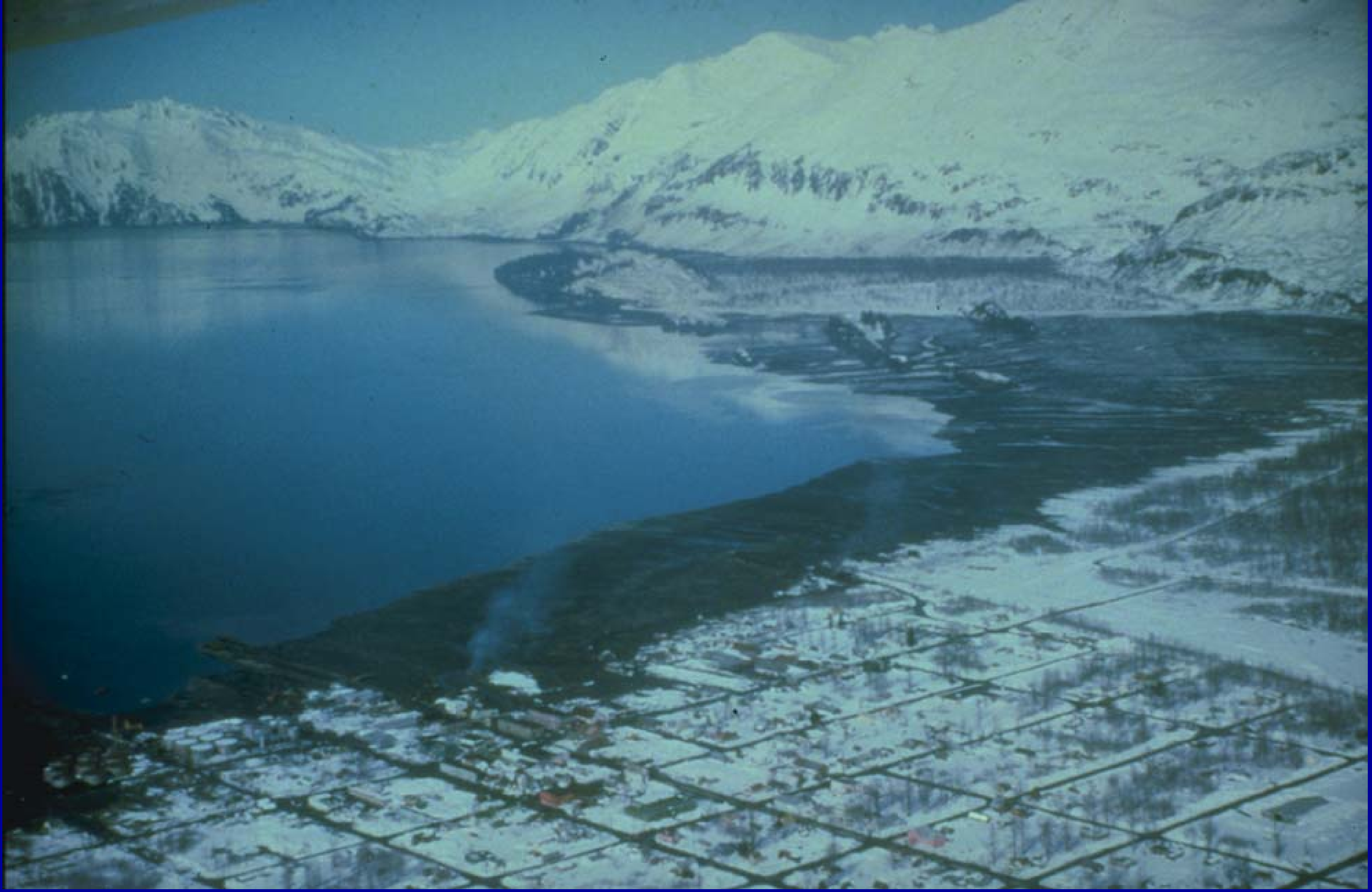
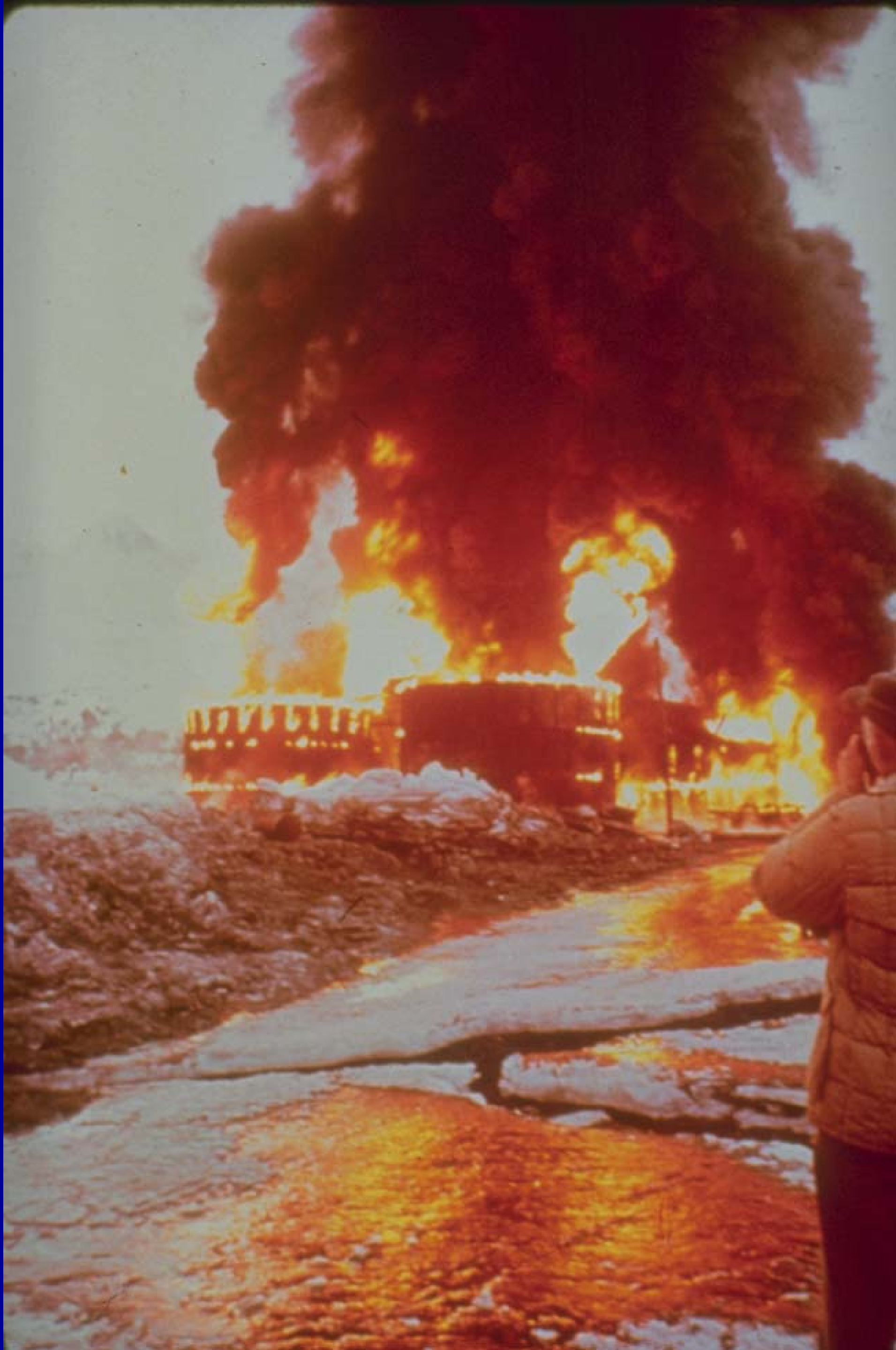


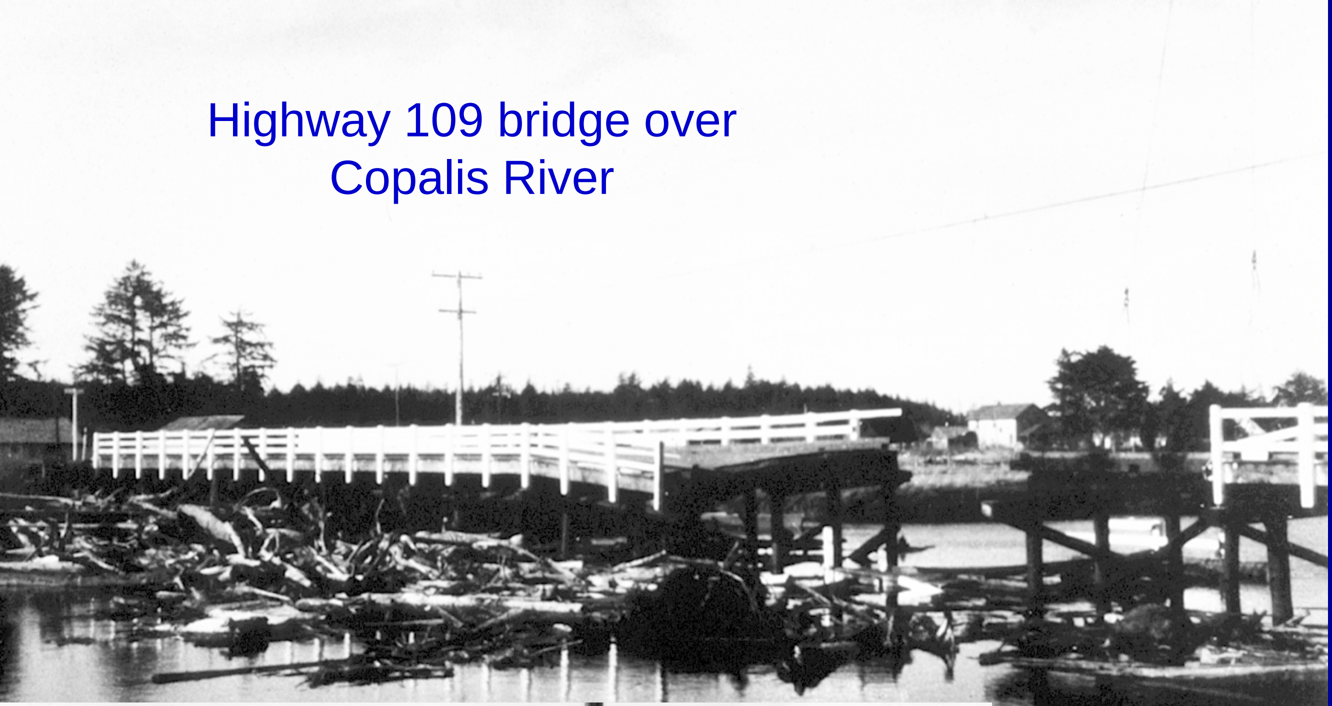
Valdez sits on the edge of an outwash delta 150 km from the epicenter. During the shaking, the unstable, saturated material failed. A slice of the delta, 1,220 m long and 183 m wide, slid into the sea, carrying the docks and part of the town with it. The slide generated a wave which slammed the waterfront 2 to 3 minutes after the onset of the quake. The wave demolished the rest of the waterfront, destroyed the fishing fleet, and reached 2 blocks into town, killing 30 people

Fire at Valdez, Alaska. The tank fire was triggered by failure of oil storage tanks at the Union Oil tank farm. By 10:30 p.m. about 5 hours after the quake, the whole waterfront was burning furiously. Some buildings along Front Street and Standard Oil's pumping control station also caught fire. The Union Oil tank farm continued to burn for two weeks.

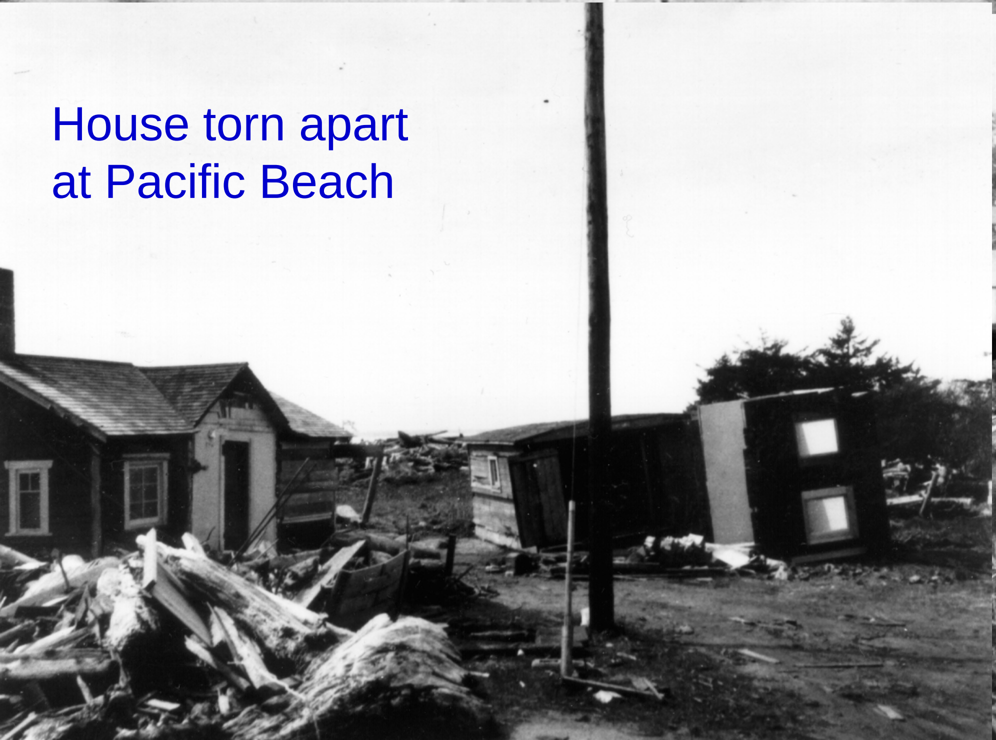


Tsunami damage from the 1964 Alaska earthquake

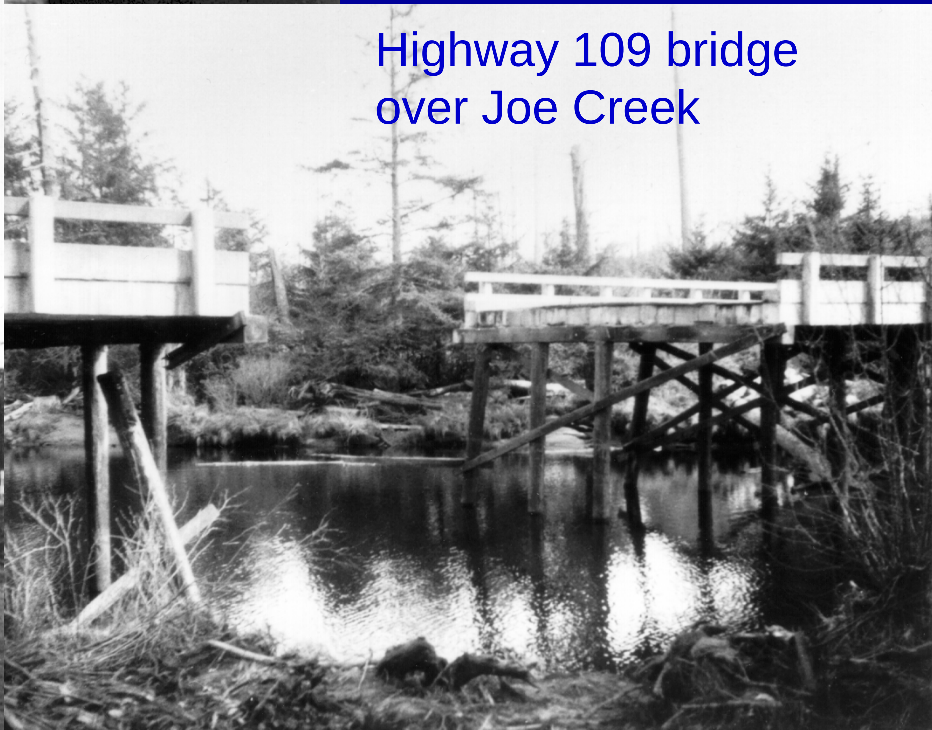
The wave here was about 10-12 feet.



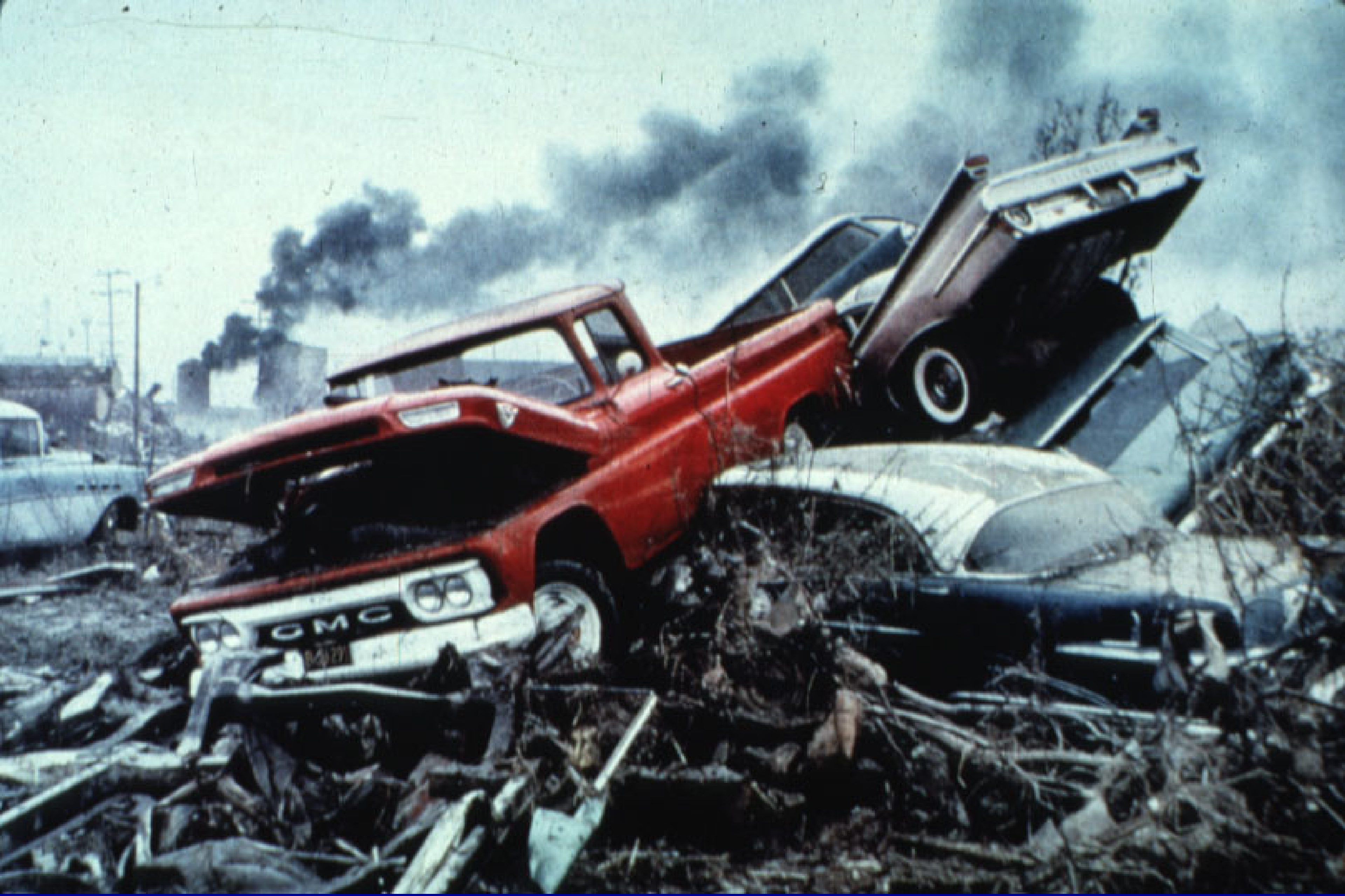
Highway 109 bridge over Copalis River



House torn apart at Pacific Beach

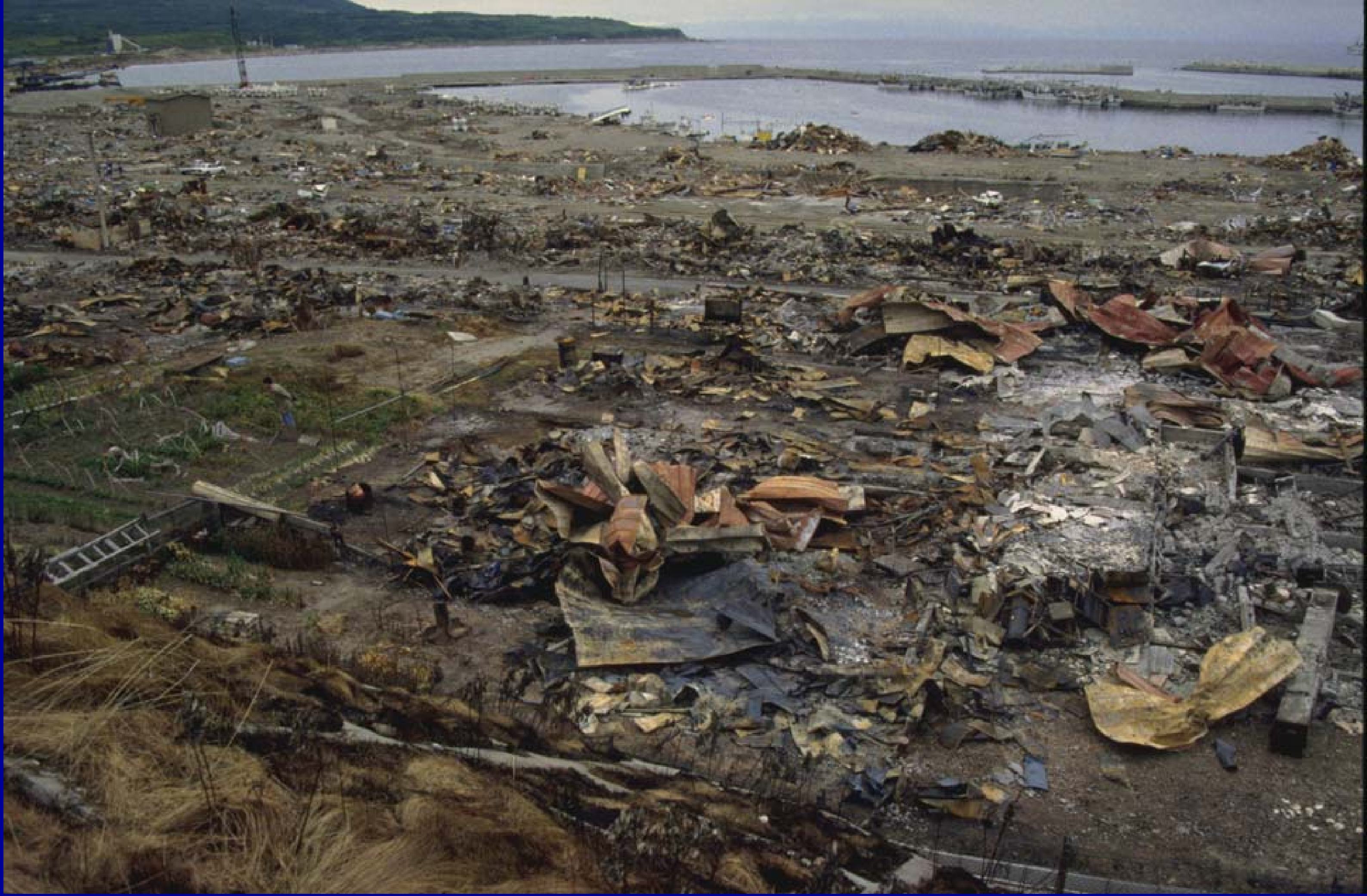


Highway 109 bridge over Joe Creek

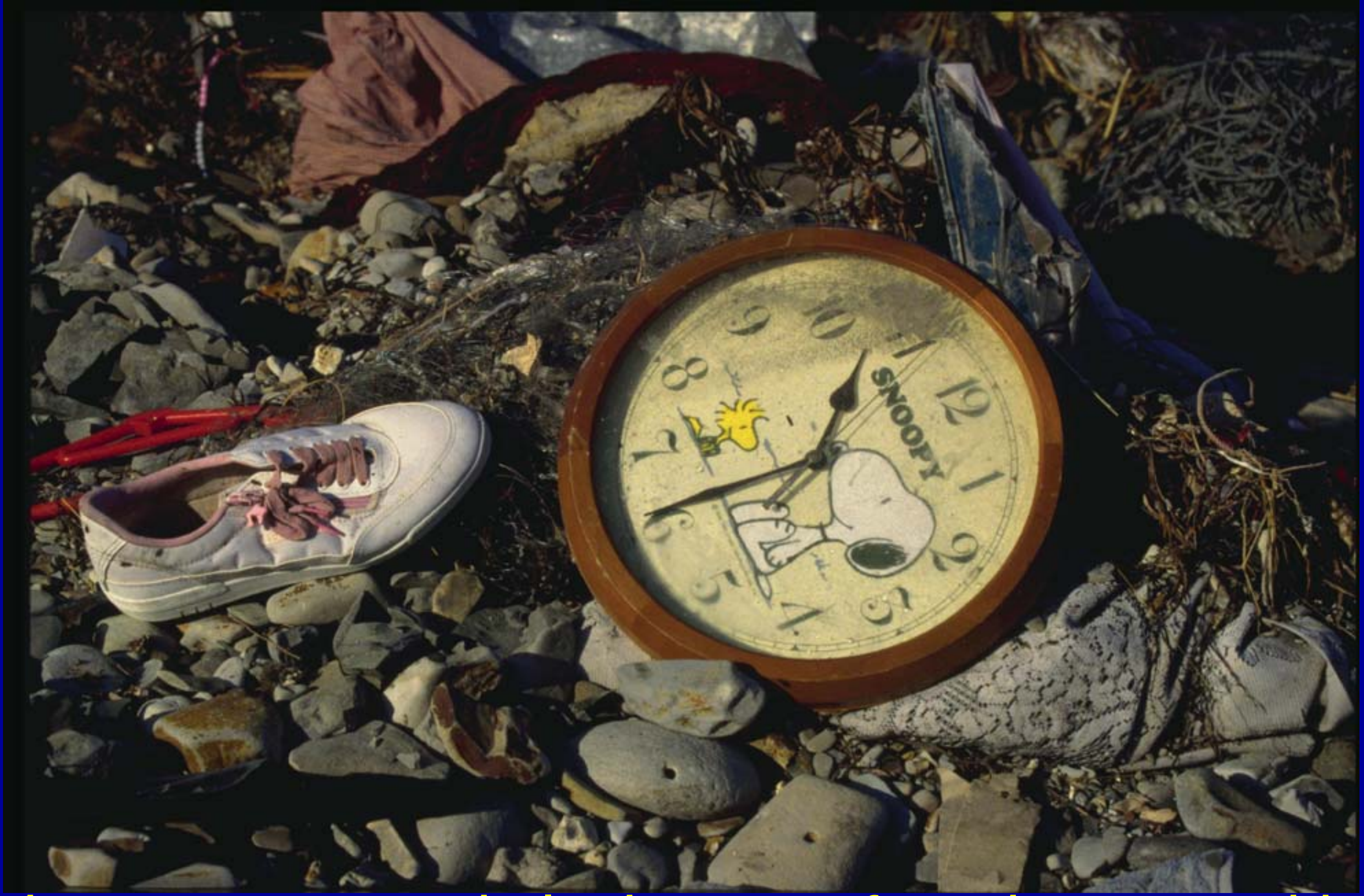


This earthquake also generated a Pacific Ocean-wide tsunami that killed 110 people, 8 here in Crescent City, CA. Note fire in background.

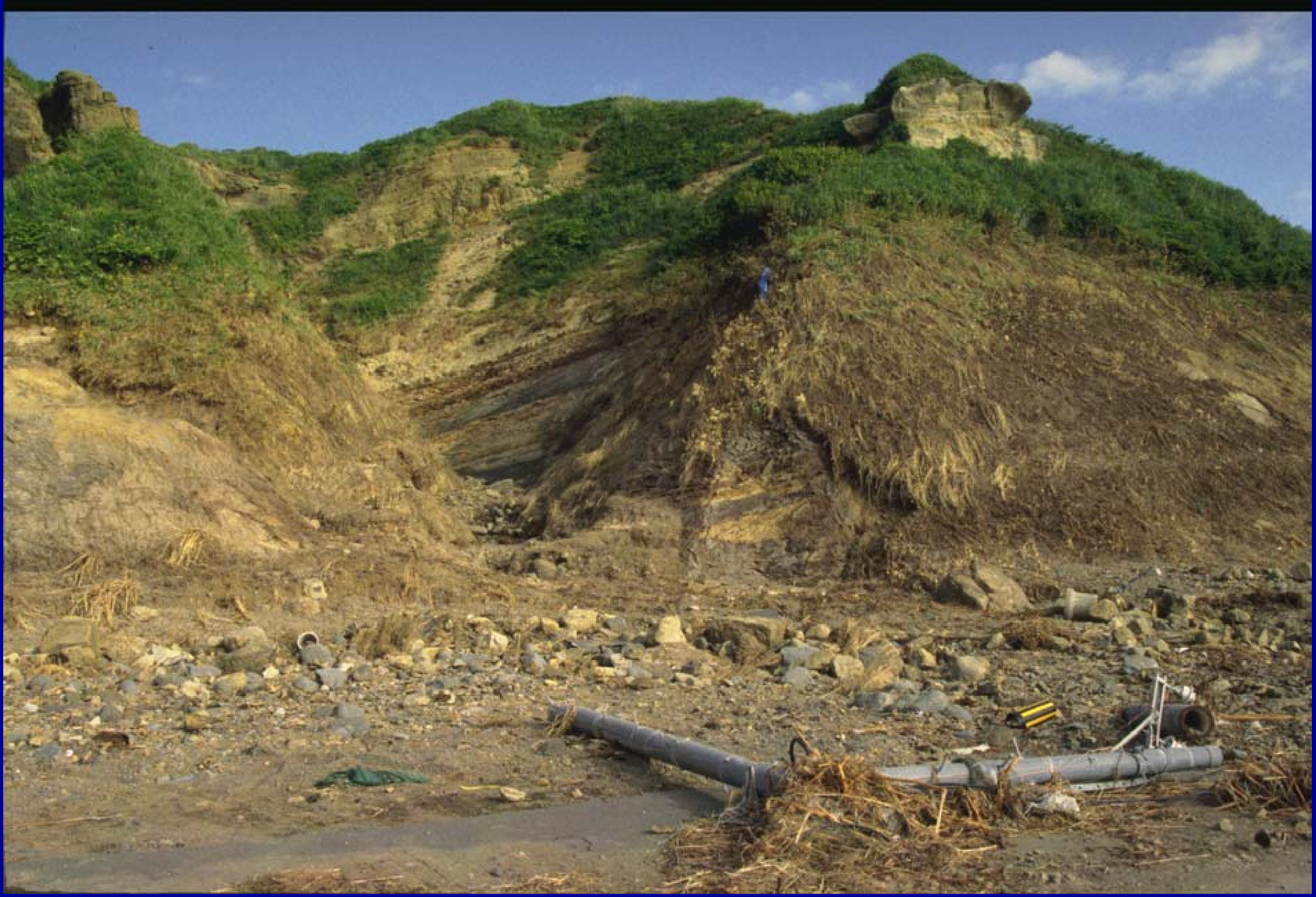
1993 Okushiri Island



- A view of tsunami and related fire damage on southeast Okushiri Island in the community of Aonae. Photo orientation is looking northeast. Numerous fires broke out following the tsunami, adding to the property loss and misery. More than 120 people were killed in Japan (Okushiri and Hokkaido Islands) by the tsunami.

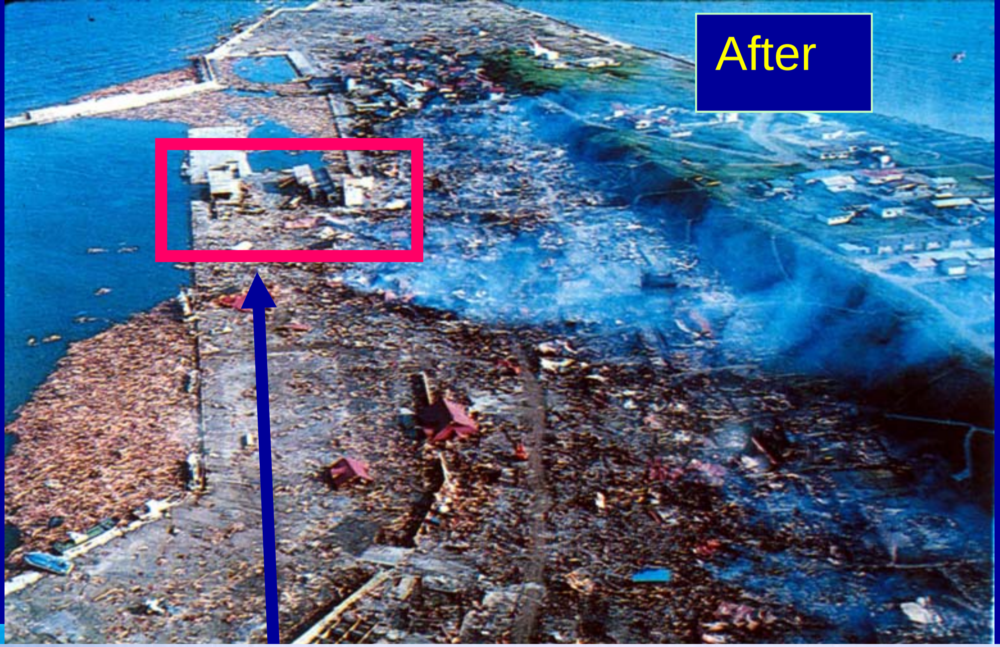


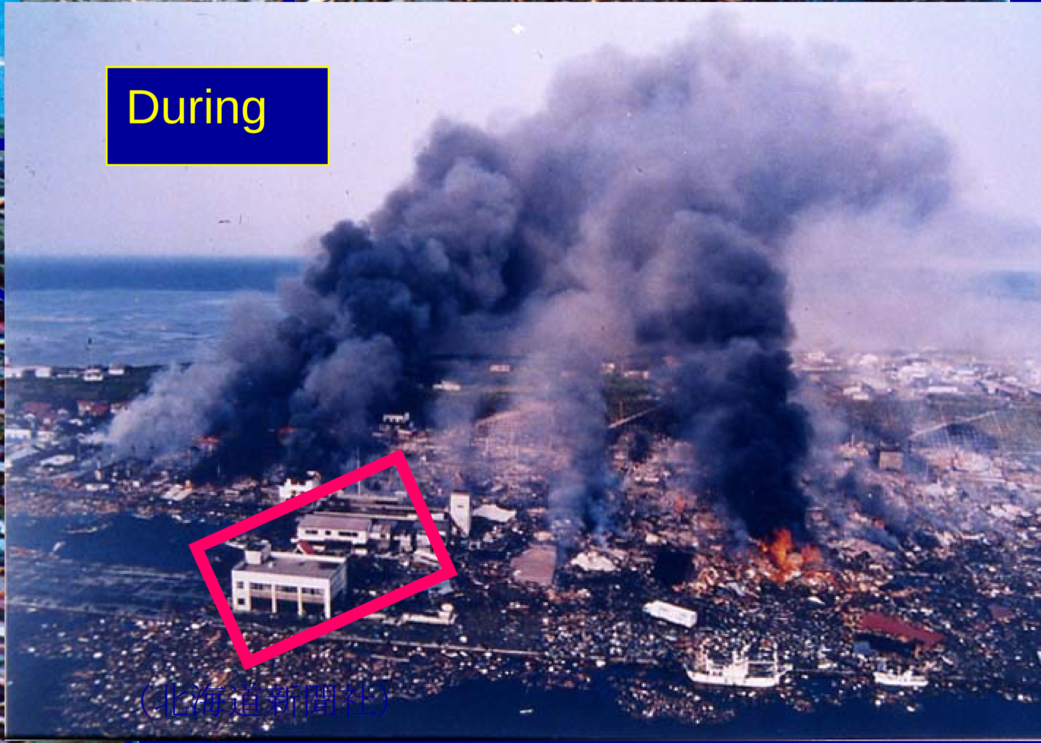
Numerous battery-operated clocks were found scattered in the debris, providing a rough estimate of the arrival time of inundating, destructive waves. The salt water shorted this clock, causing it to stop. This clock at Aonae, Okushiri Island, shows a travel time (not necessarily for the first wavebut the first inundating wave at this specific location in Aonae) of some fifteen minutes following the earthquake. Clocks on the west side of Okushiri Island showed travel times of as little as six to seven minutes.



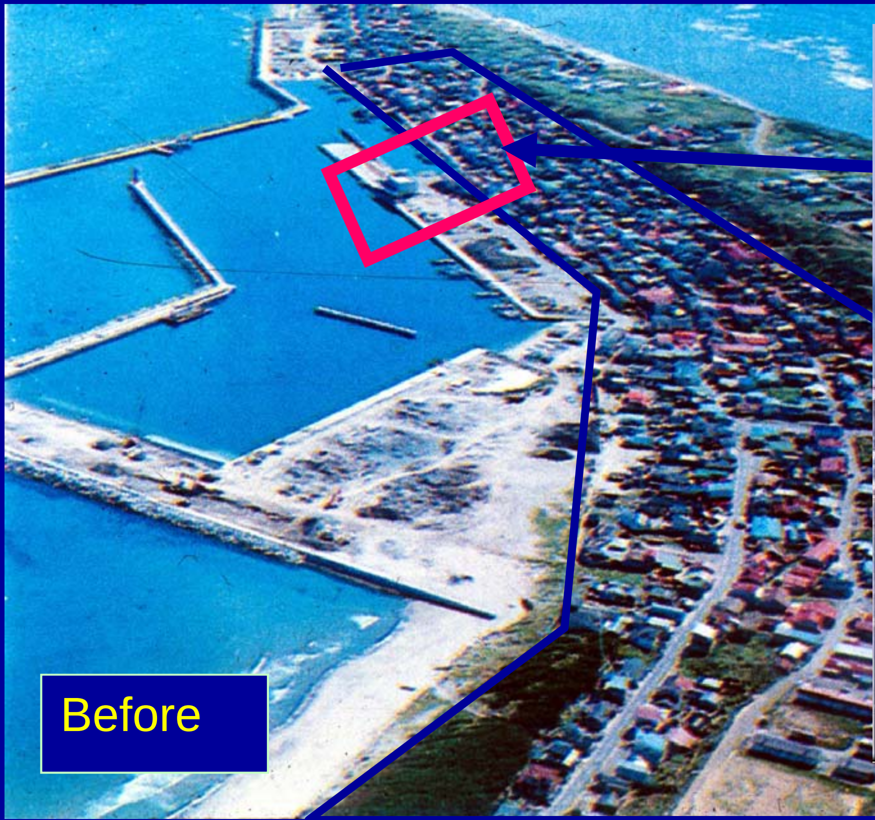
- On the west side of Okushiri Island many locations experienced a maximum runup of over 20 m. This small valley leading to the ocean experienced a spectacular runup of 31 m. Note the debris in the foreground, including a broken steel reinforced concrete utility pole. Discolored and dead plants and grasses are evident on the hillside.

TWO BUILDINGS IN AONAE, 1993


After

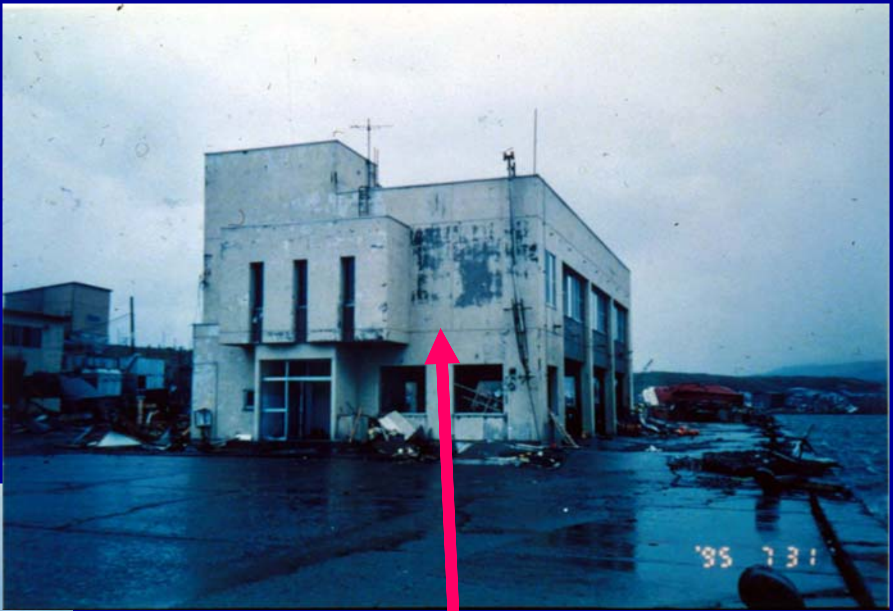

During

（北海道新聞社）

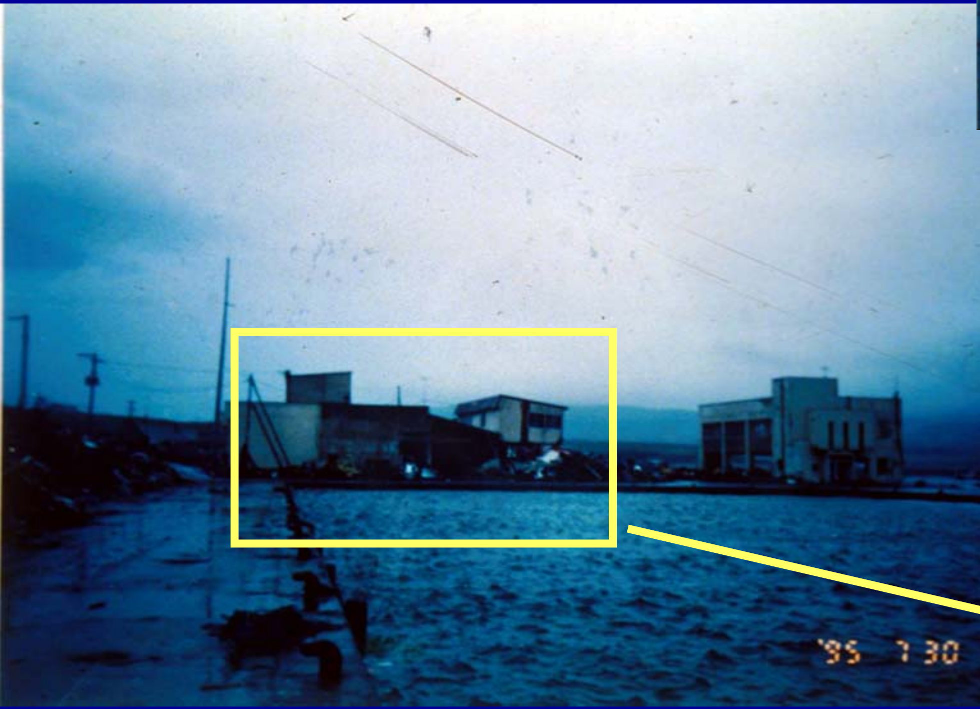

Before

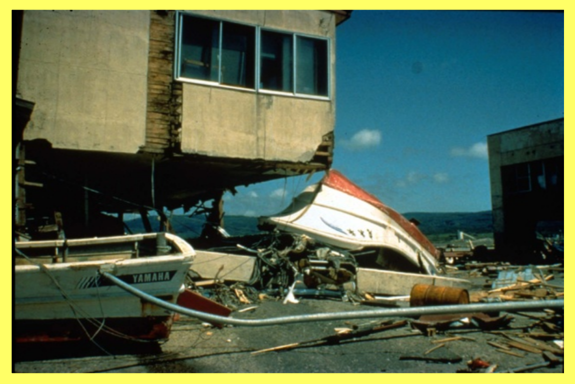
from Nobuo Shuto

THE TWO BUILDINGS THAT REMAINED.



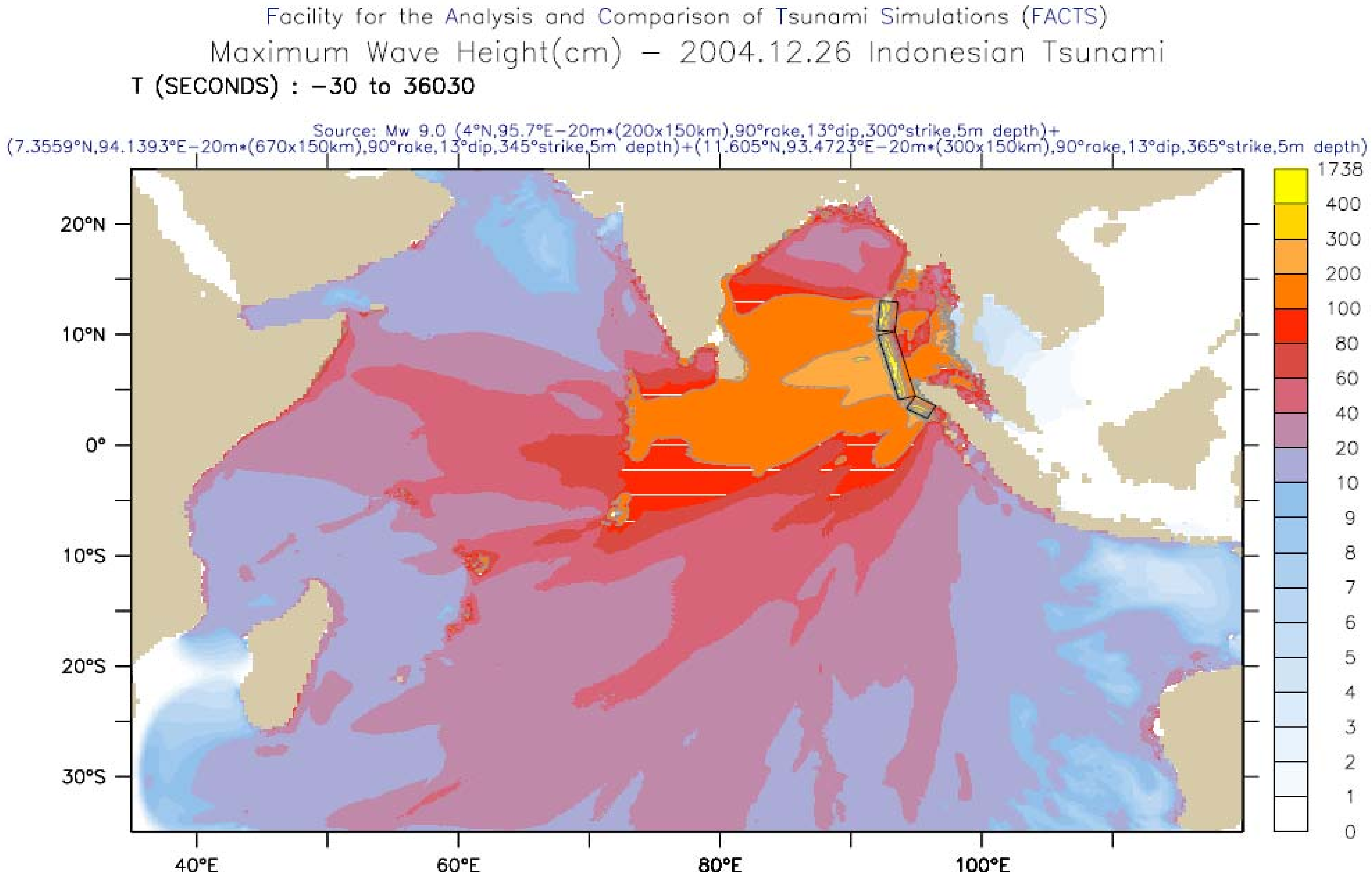
Tsunami trace





This building stopped a house and boats.

Indian Ocean, December 26, 2004


Facility for the Analysis and Comparison of Tsunami Simulations (FACTS)
Maximum Wave Height(cm) – 2004.12.26 Indonesian Tsunami
T (SECONDS) : –30 to 36030
Source: Mw 9.0 (4°N,95.7°E–20m*(200x150km),90°rake,13°dip,300°strike,5m depth)+
(7.3559°N,94.1393°E–20m*(670x150km),90°rake,13°dip,345°strike,5m depth)+(11.605°N,93.4723°E–20m*(300x150km),90°rake,13°dip,365°strike,5m depth)
20°N
10°N
0°
10°S
20°S
30°S
40°E
60°E
80°E
100°E
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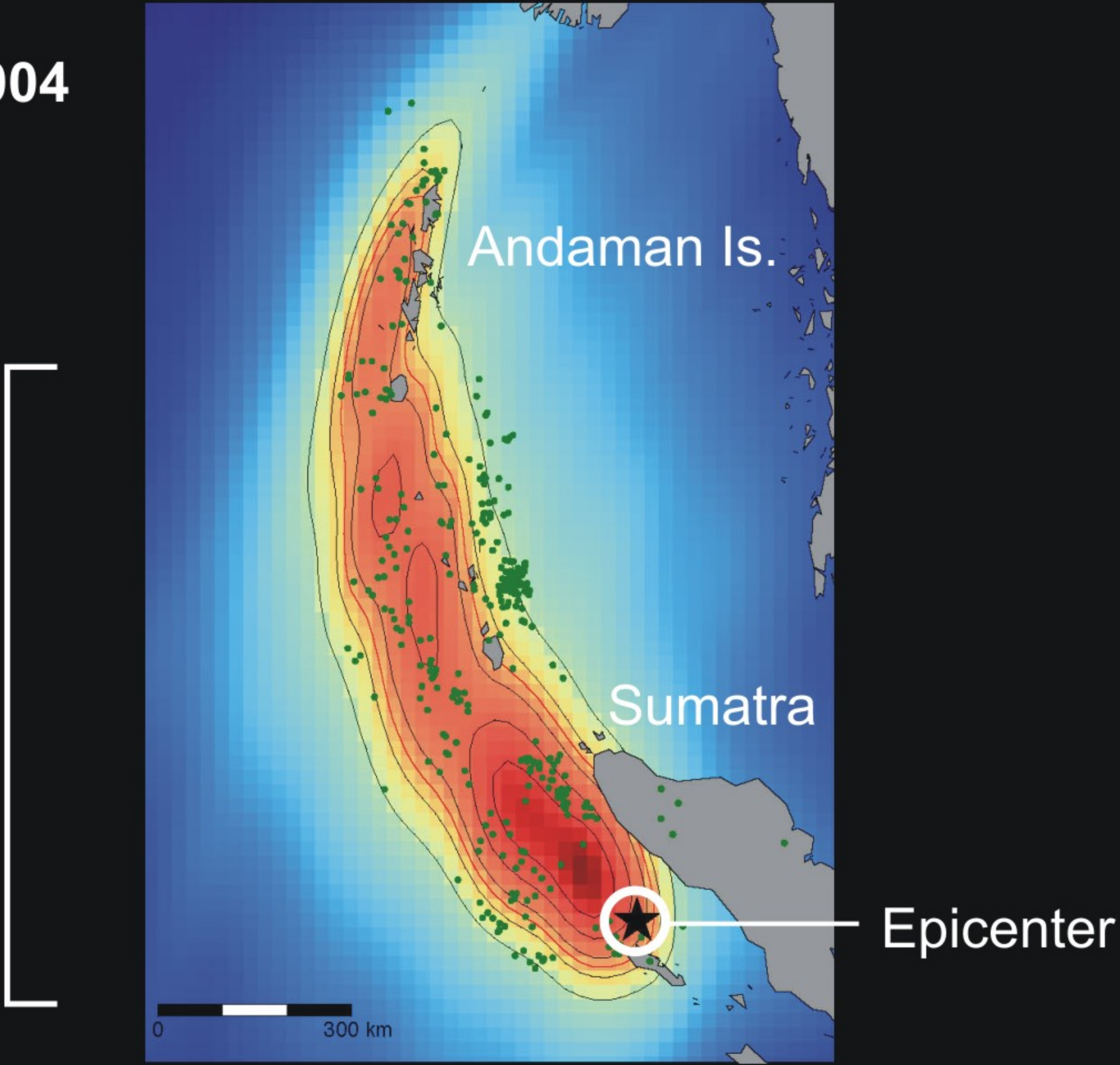
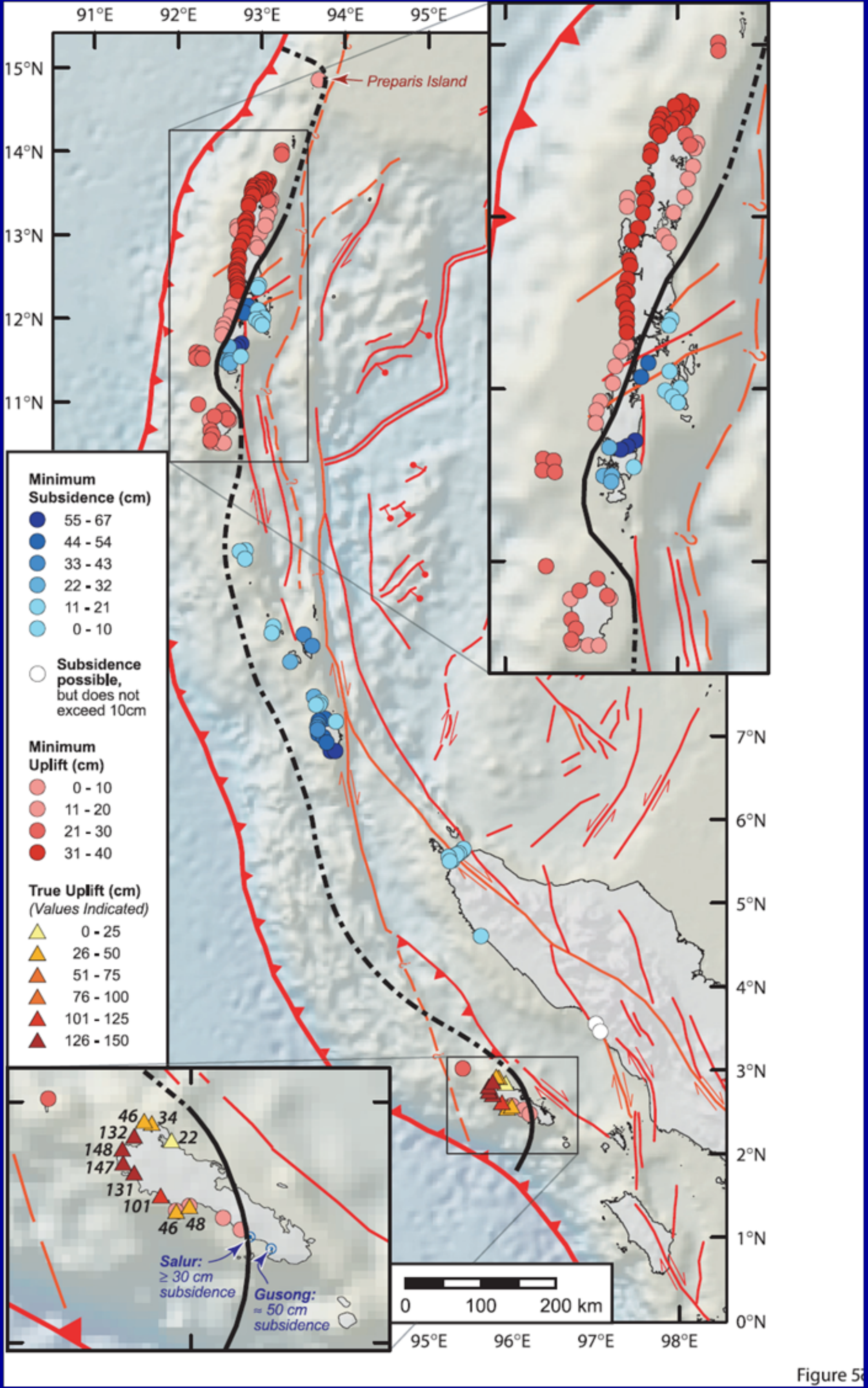
M 9 rupture in 2004



Ishii, Shearer, Houston, and Vidale

In Sumatra and the Andaman Islands, uplifts of 5 feet and subsidence of at least 2 feet were measured, but larger values are likely



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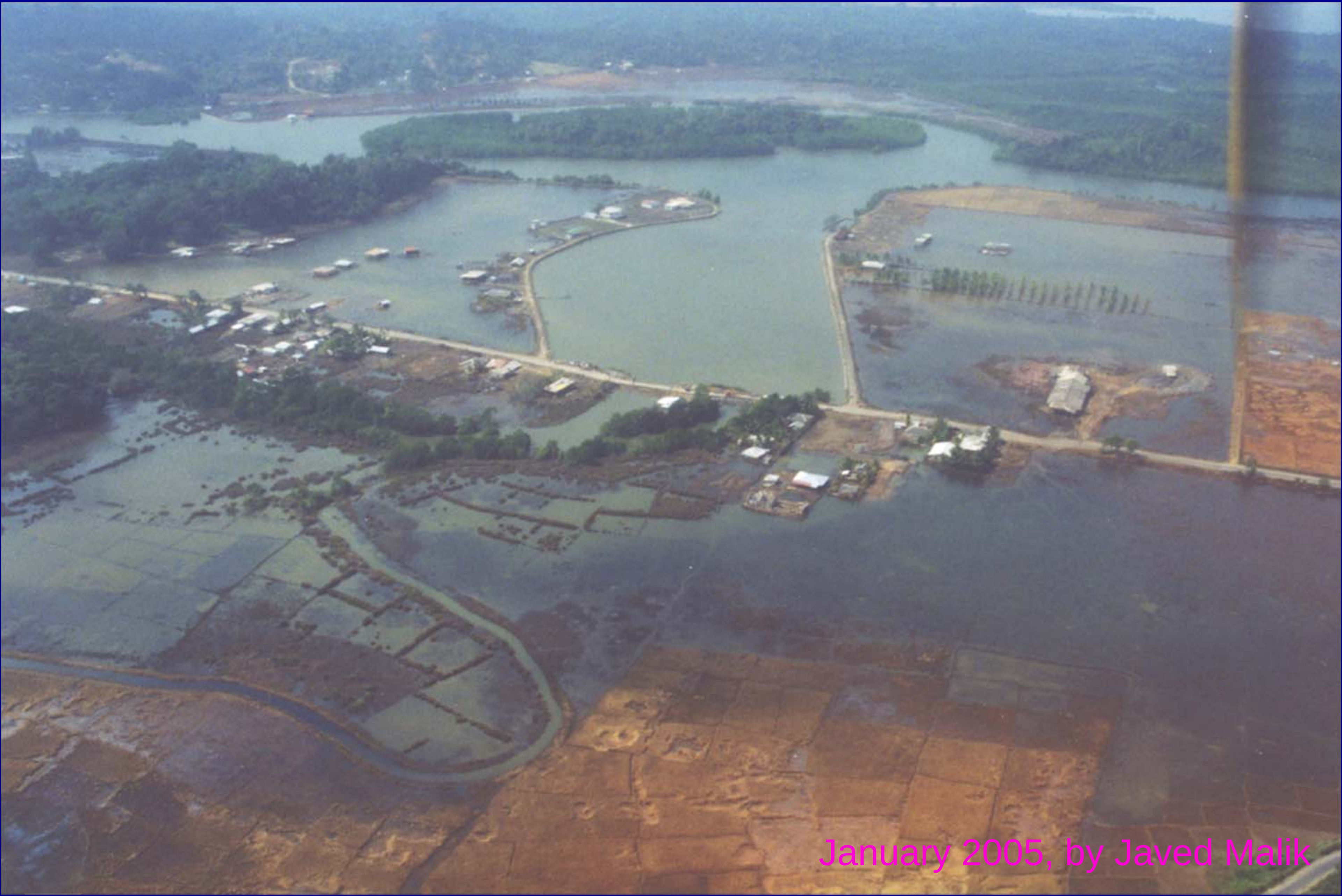
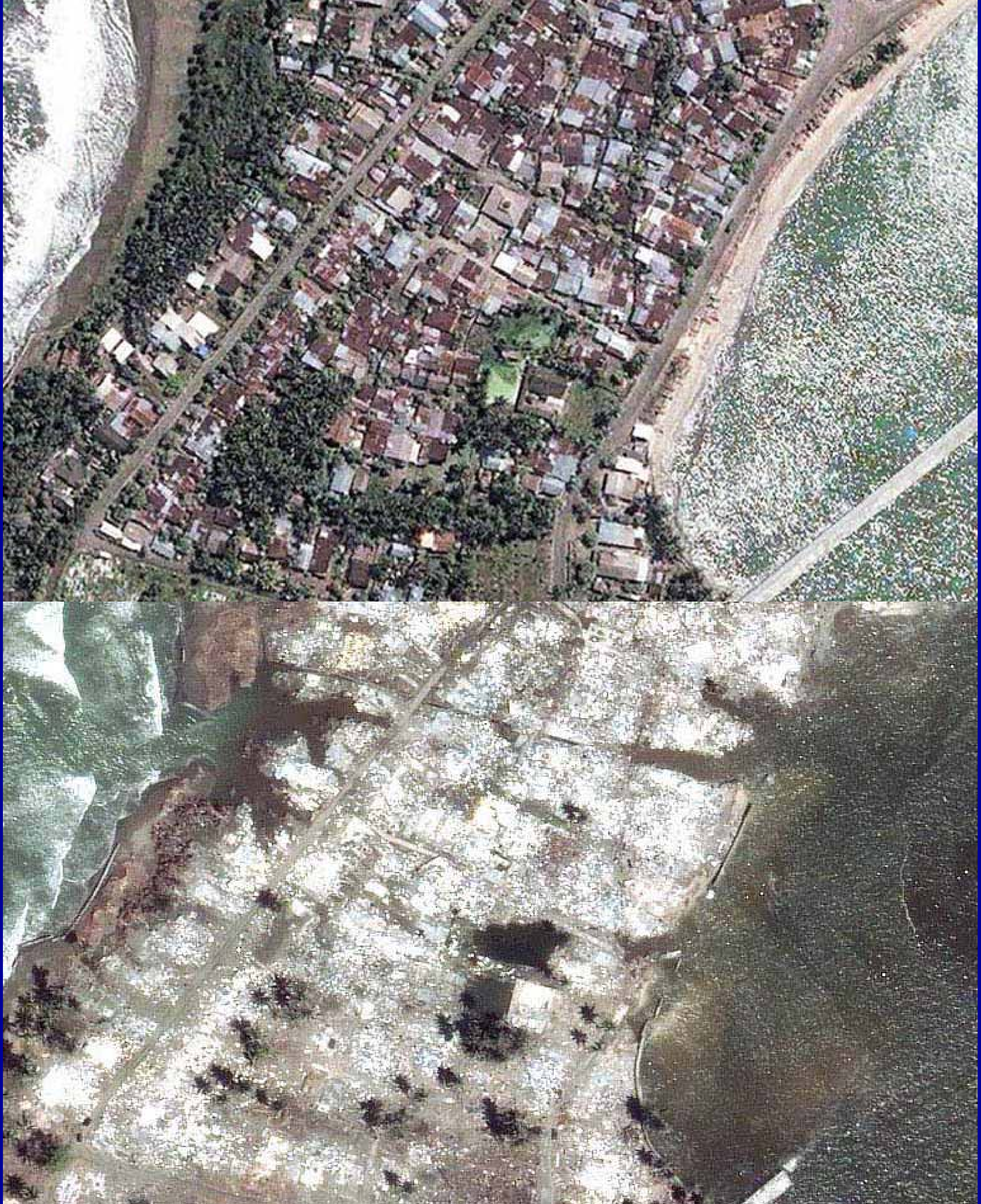
Subsidence, South Andaman Island



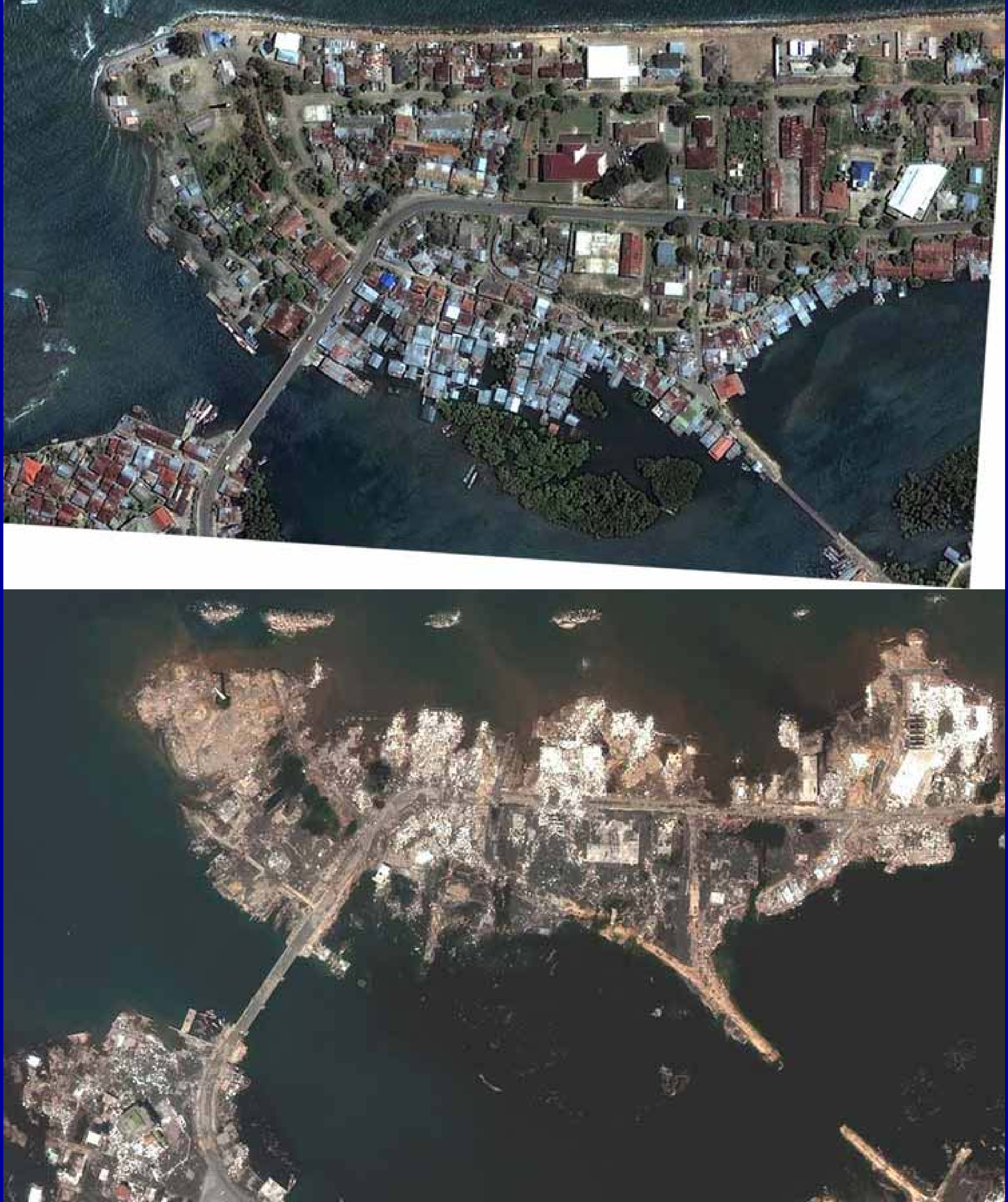
January 2005, by Javed Malik

Banda
Aceh

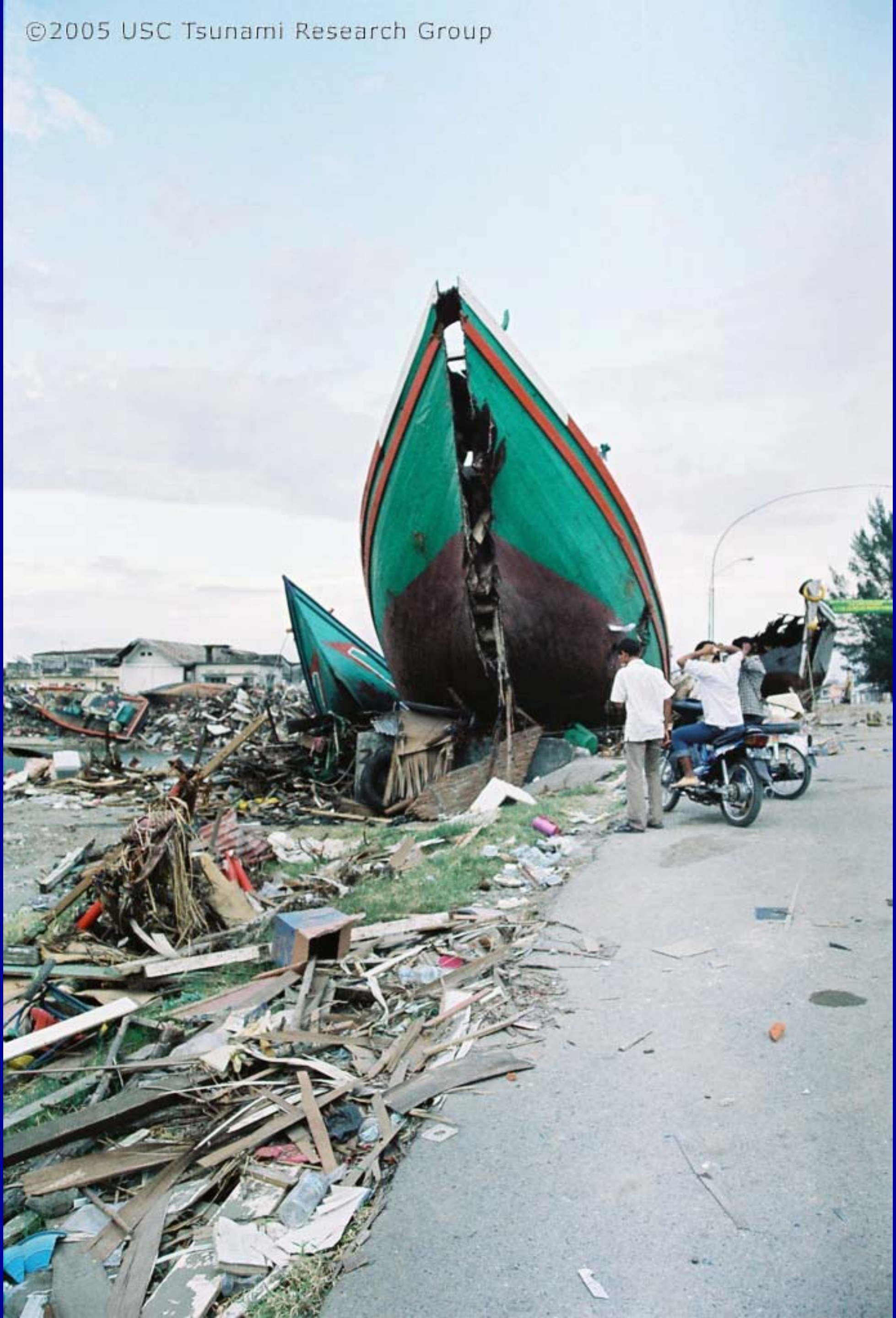


Banda

Aceh



Boats slammed into a bridge in central Banda Aceh.



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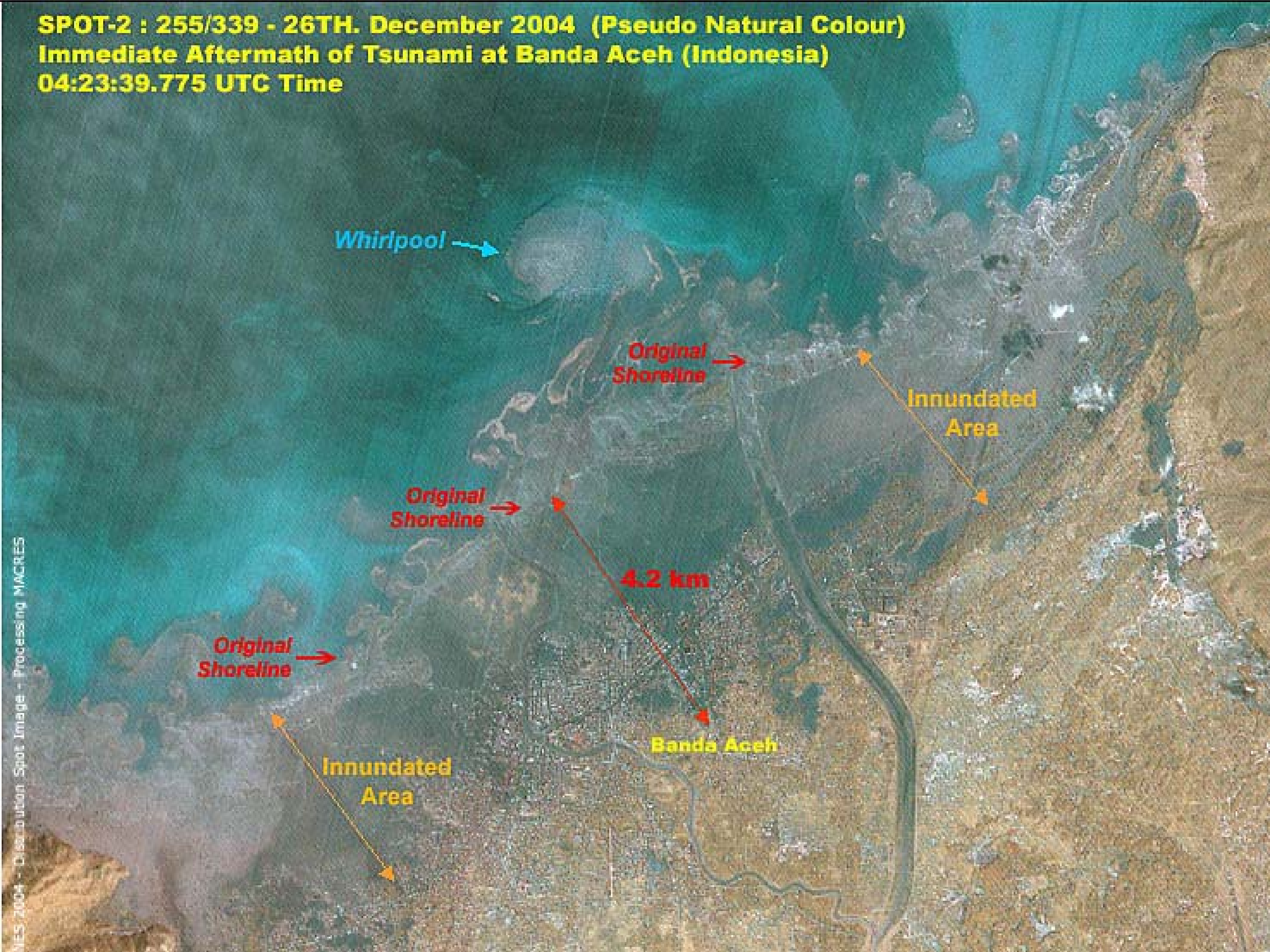
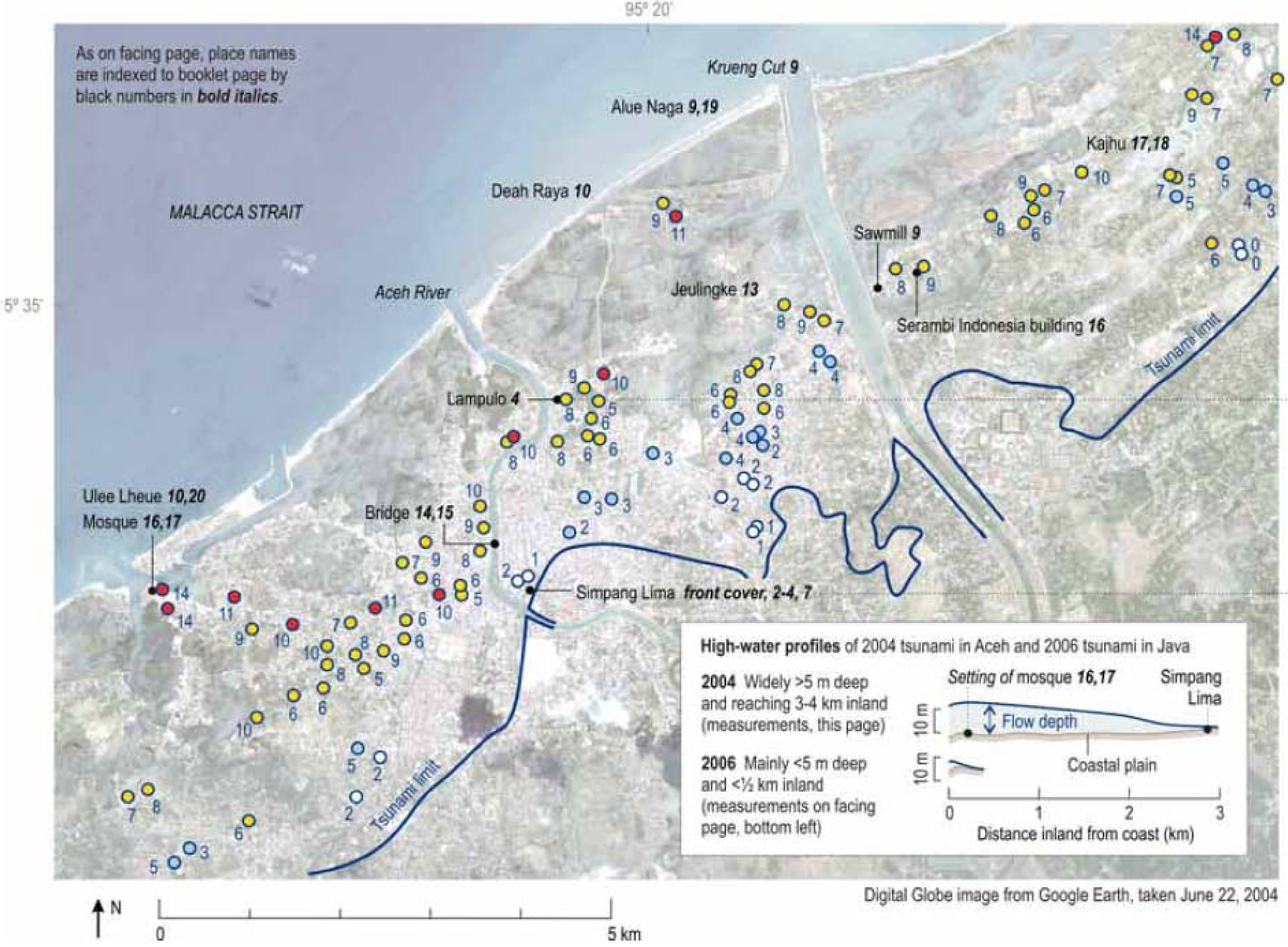


SPOT-2 : 255/339 - 26TH. December 2004 (Pseudo Natural Colour)
Immediate Aftermath of Tsunami at Banda Aceh (Indonesia)
04:23:39.775 UTC Time

NES 2004 - Distribution Spot Image - Processing MACRES

Banda Aceh and vicinity



As on facing page, place names are indexed to booklet page by black numbers in ***bold italics***.

High-water profiles of 2004 tsunami in Aceh and 2006 tsunami in Java

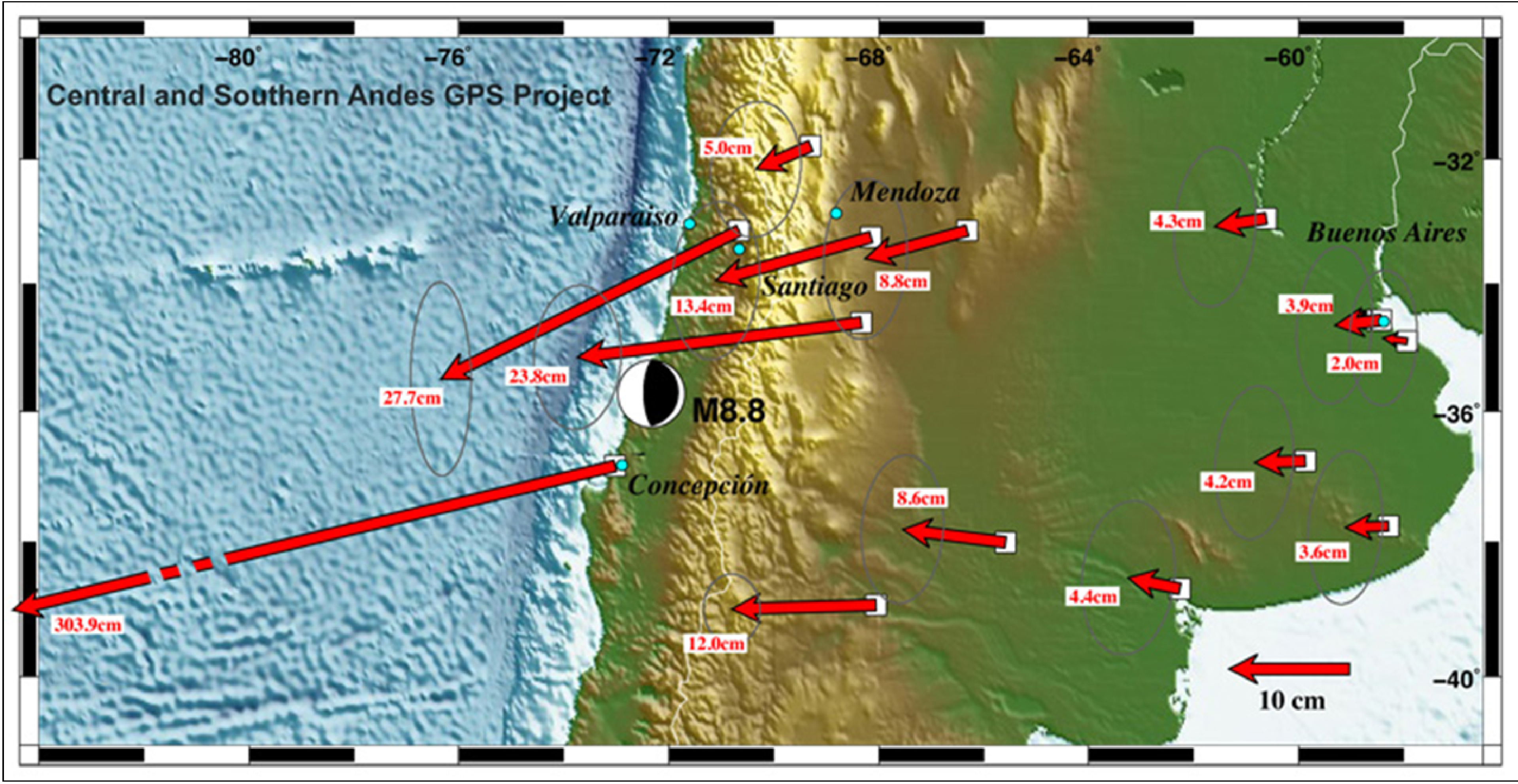
2004 Widely >5 m deep and reaching 3-4 km inland (measurements, this page)

2006 Mainly <5 m deep and <½ km inland (measurements on facing page, bottom left)

Digital Globe image from Google Earth, taken June 22, 2004

Eksklusif
Metro TV
NEWS
channel
HEADLINE NEWS

Southern Chile, February 27, 2010



Preliminary Coseismic Displacement Field M 8.8 Maule Earthquake, Chile, Feb 27 2010

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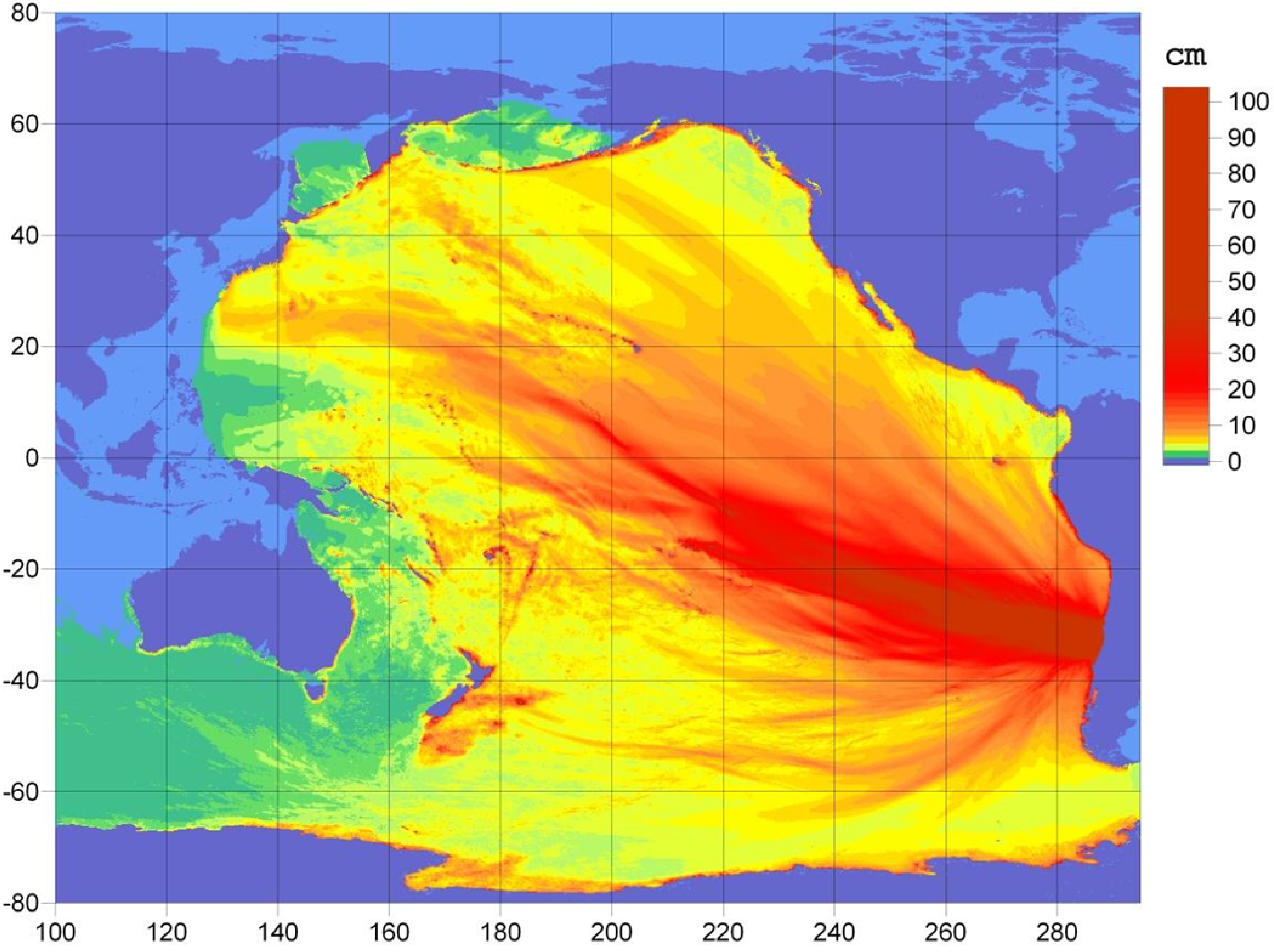
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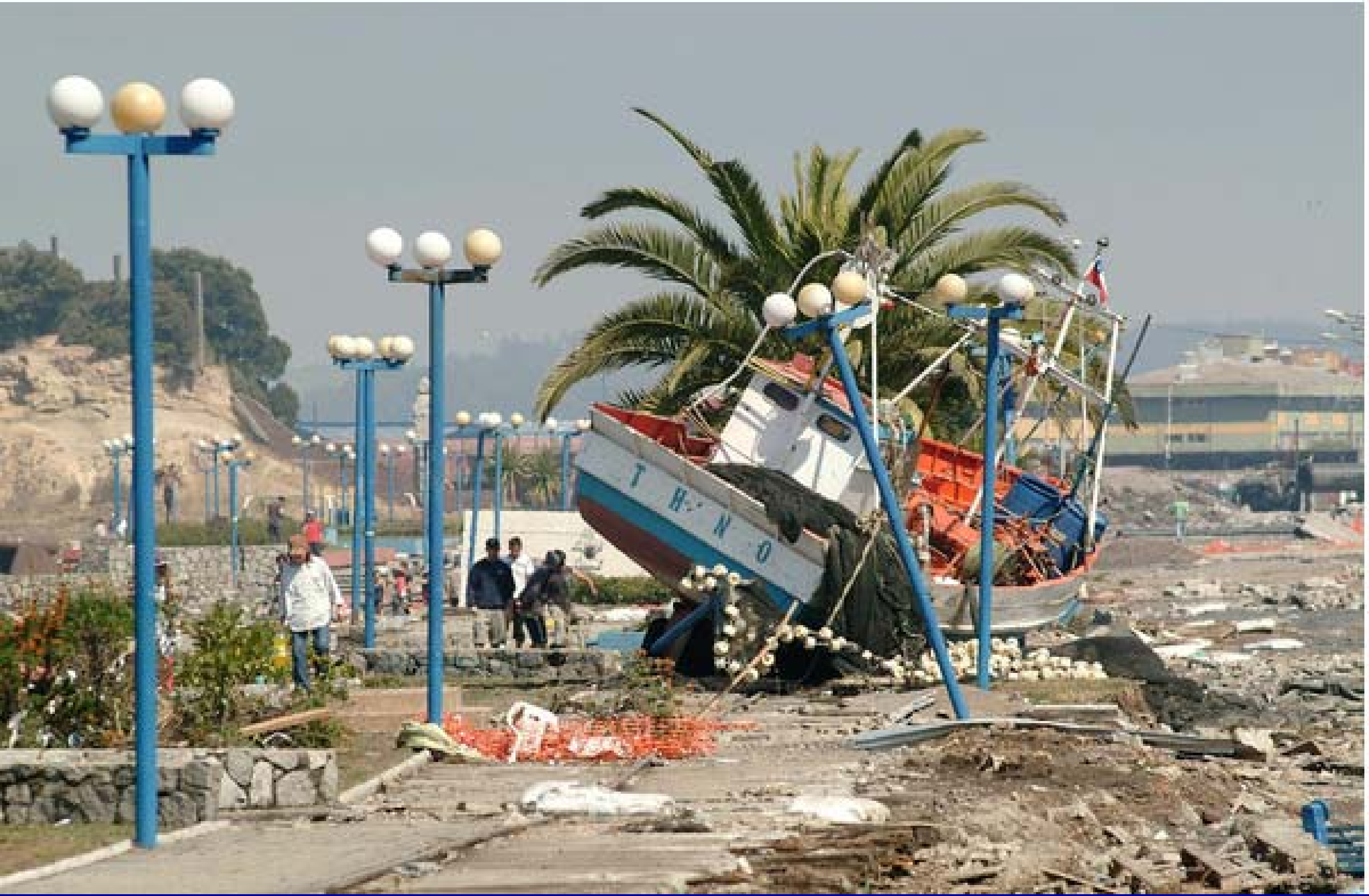
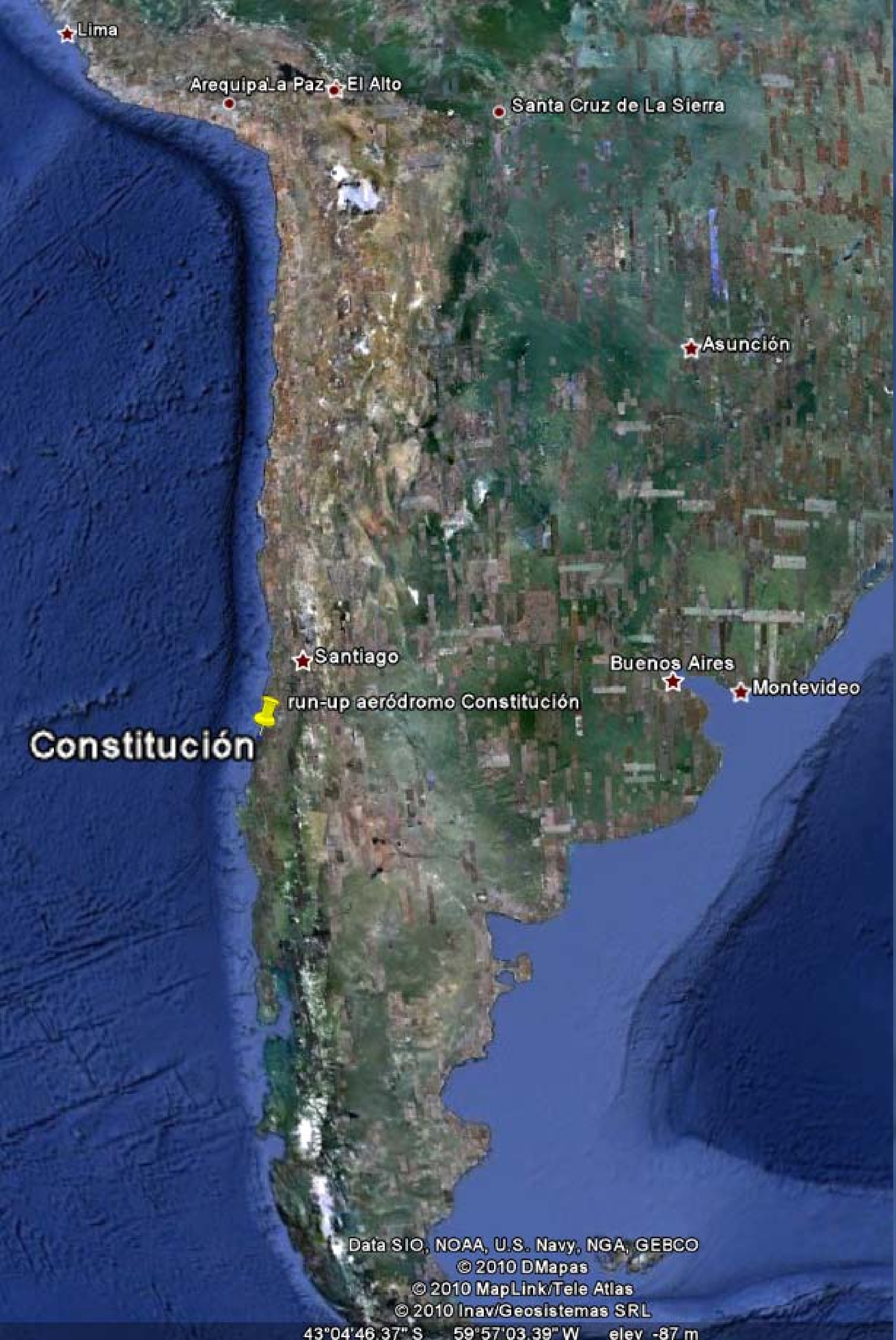


Talcahuano, Chile, February 28, 2010


Lima
Arequipa
La Paz
El Alto
Santa Cruz de La Sierra
Asunción
Santiago
Buenos Aires
Montevideo
run-up aeródromo Constitución
Constitución
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2010 DMapas
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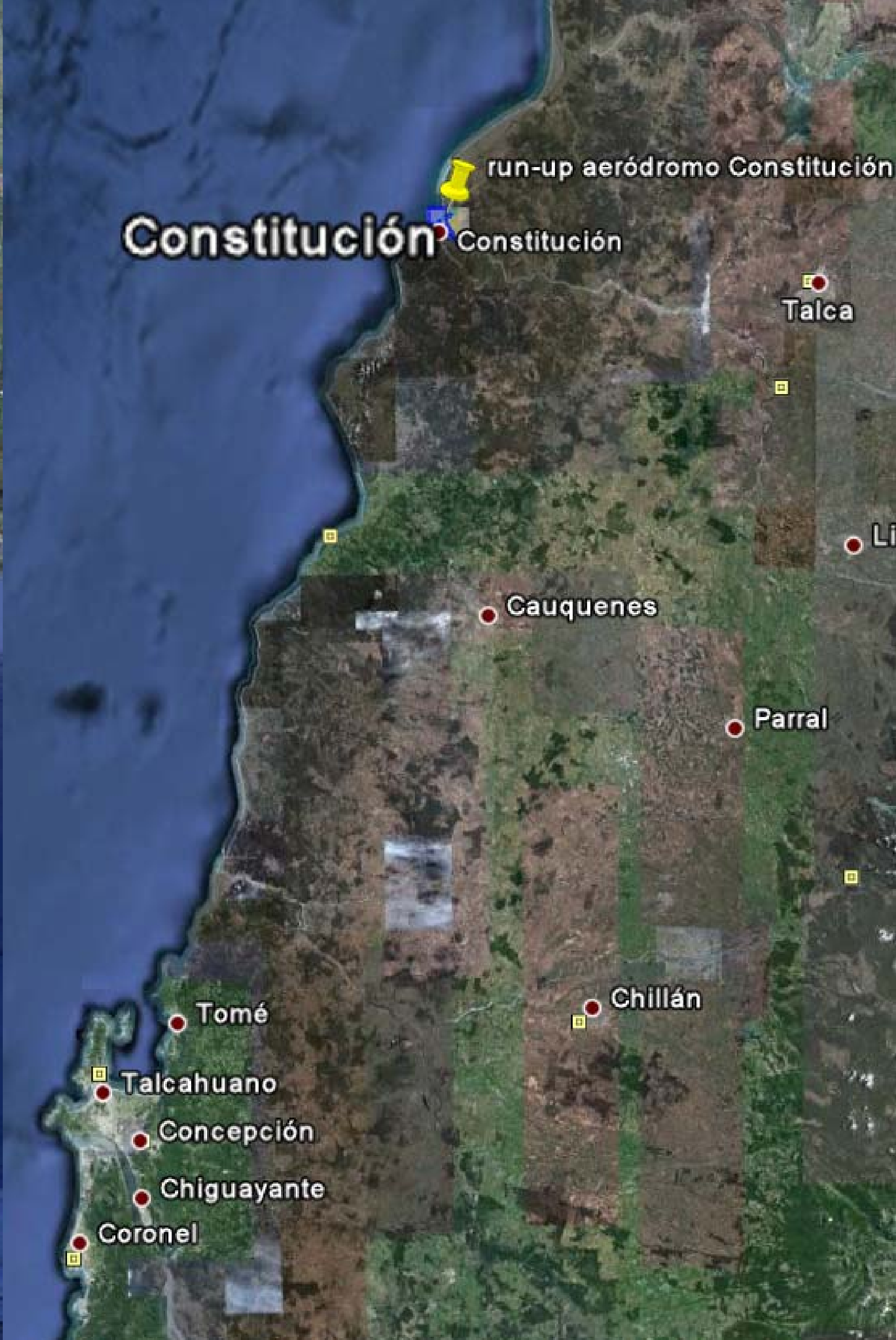
© 2010 Inav/Geosistemas SRL
43°04'46.37" S 59°57'03.39" W elev -87 m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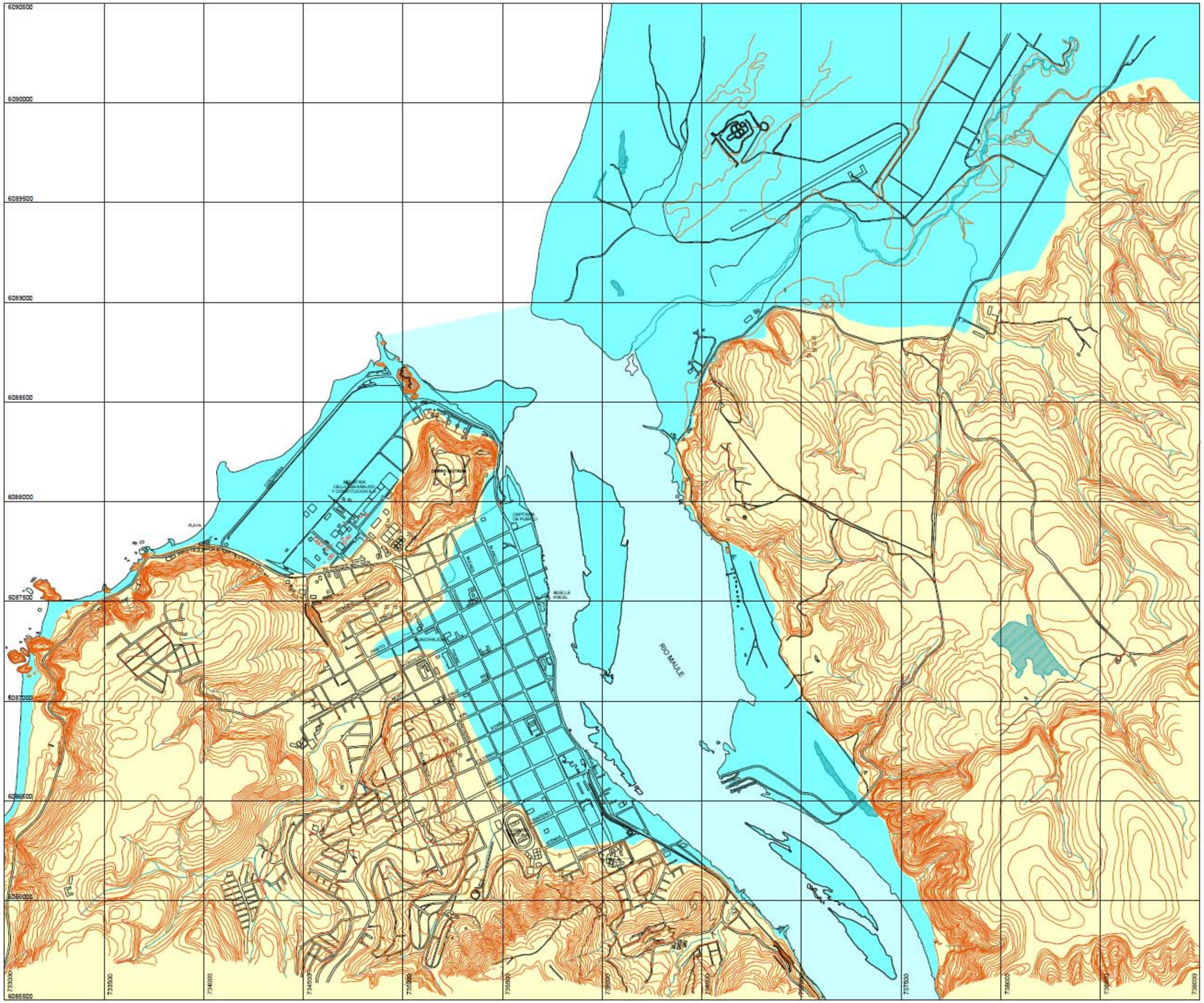


CONSTITUCION

CARTA DE INUNDACION POR TSUNAMI

REFERIDA AL EVENTO DEL AÑO 1835
POR EL SERVICIO HIDROGRAFICO Y OCEANOGRAFICO DE LA ARMADA DE CHILE

Escala 1 : 10.000
Coordenadas U.T.M. - Datum Geodésico WGS-84
Meridiano Central 75

0 200 400 600 800 1000m

🟦 AREA INUNDADA
▨ DETALLE URBANO
▨ CURVAS DE NIVEL

MEMORIA EXPLICATIVA CARTA DE INUNDACION POR TSUNAMI PARA EL PUERTO CONSTITUCION

INTRODUCCION

Las características geotectónicas y morfológicas de la zona centro sur de Chile, asociadas a su potencial sísmico, son determinantes al momento de evaluar la vulnerabilidad de la zona urbana costera del puerto Constitución frente al riesgo de tsunami. Dentro de este contexto, la determinación de las áreas inundables por un tsunami extremo en la ciudad constituye un aspecto fundamental que condiciona la efectividad de los planes locales de Protección Civil y el manejo de las áreas que potencialmente puedan ser afectadas.

Para ello, el Servicio Hidrográfico y Oceanográfico de la Armada (SHOA) ha elaborado una cartografía de inundación por tsunami correspondiente a la zona urbana de Constitución, basándose en los resultados de la aplicación de una metodología de simulación numérica, la que básicamente integra datos topográficos, batimétricos y sísmicos, para resolver un modelo numérico de simulación mediante el uso de computadoras.

TSUNAMIS EN CONSTITUCION

Históricamente, se conoce la ocurrencia de por lo menos cinco terremotos que generaron ondas de tsunami en el puerto Constitución. Estos son: el registrado en 1570, el 8 de julio de 1730, el 25 de mayo de 1751, el 20 de febrero de 1835 y finalmente el ocurrido durante el siglo XX, el del 16 de agosto de 1906. Los eventos extremos de 1835 y 1906 son los mejor documentados.

CARTA DE INUNDACION POR TSUNAMI

La carta de inundación por tsunami para el puerto Constitución, TSU- 5311B, comprende toda el área costera de la ciudad. Este estudio se efectuó considerando los eventos extremos mejor documentados que se han registrado a la fecha en la zona centro-sur de Chile, es decir los terremotos tsunamigénicos de 1835 y 1906. Se utilizaron datos digitales de topografía y batimetría del área, información urbana y antecedentes sismológicos e históricos de ambos eventos sísmicos.

En la carta se muestra el contorno de la máxima inundación alcanzada por el tsunami simulado y las curvas topográficas cada 5 metros sobre el nivel medio del mar. Los resultados han sido validados considerando la información histórica disponible y los estudios científicos recientes del terremoto de 1835.

Se hace notar que, con relación a los niveles de inundación señalados en la carta, en la realidad podrían ocurrir algunas variaciones respecto a los resultados de la simulación, puesto que el modelo numérico aplicado no considera aspectos hidrodinámicos asociados a la disipación de la energía del tsunami al llegar a la costa, debido a construcciones civiles tales como muelles, edificios u otras obras.

Para mayor información, consultar el estudio "CARTA DE INUNDACION POR TSUNAMI PARA EL PUERTO CONSTITUCION, CHILE. DOCUMENTO EXPLICATIVO", SHOA, Octubre 2002.

Valparaíso, Impreso y Publicado por el Servicio Hidrográfico y Oceanográfico de la Armada de Chile
Es Propiedad

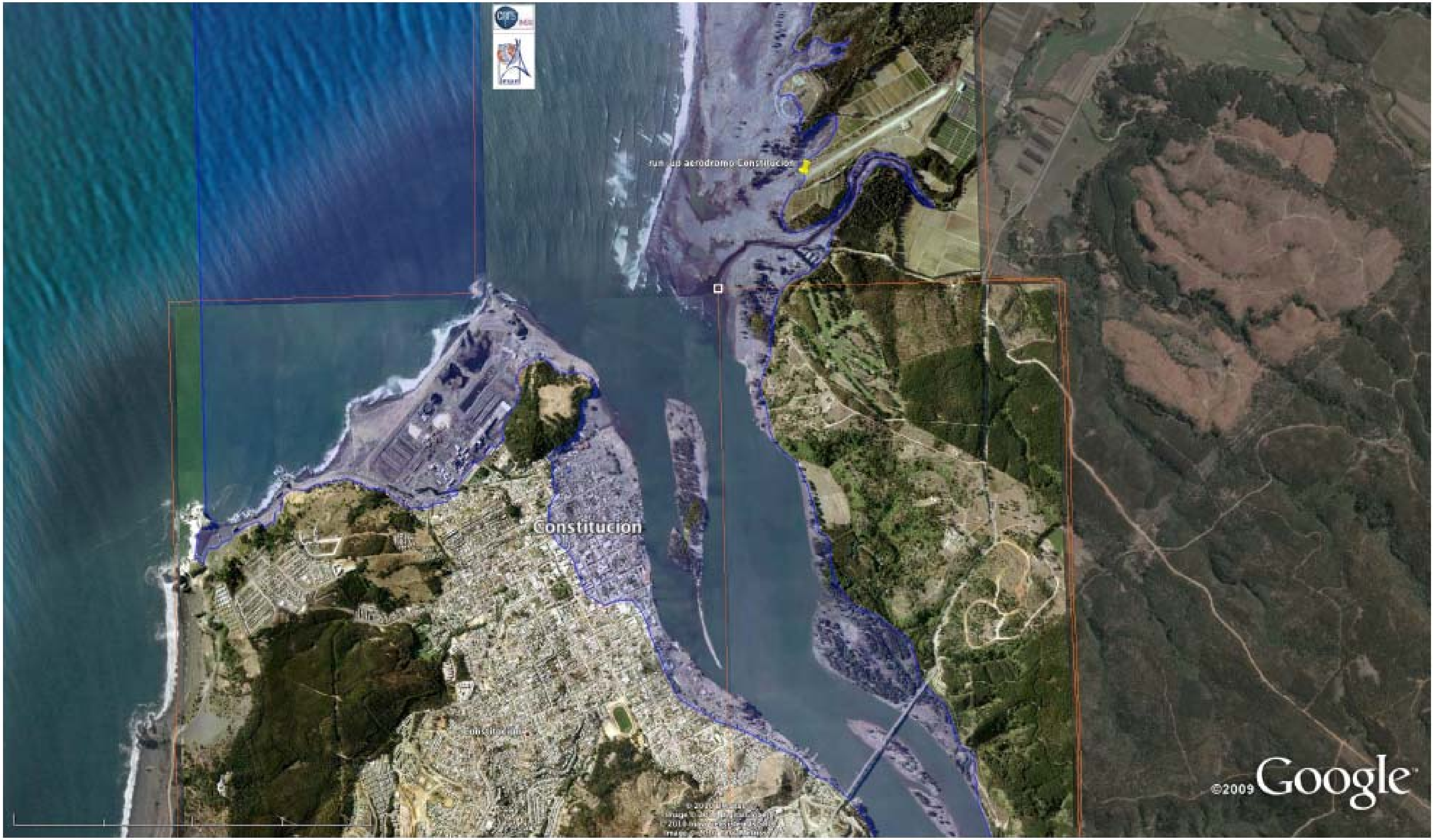


Figure 1 : Map of areas drowned by the 27/02/2010 tsunami (observed run-up in blue).
Red frame locates used post-earthquake high-resolution images.

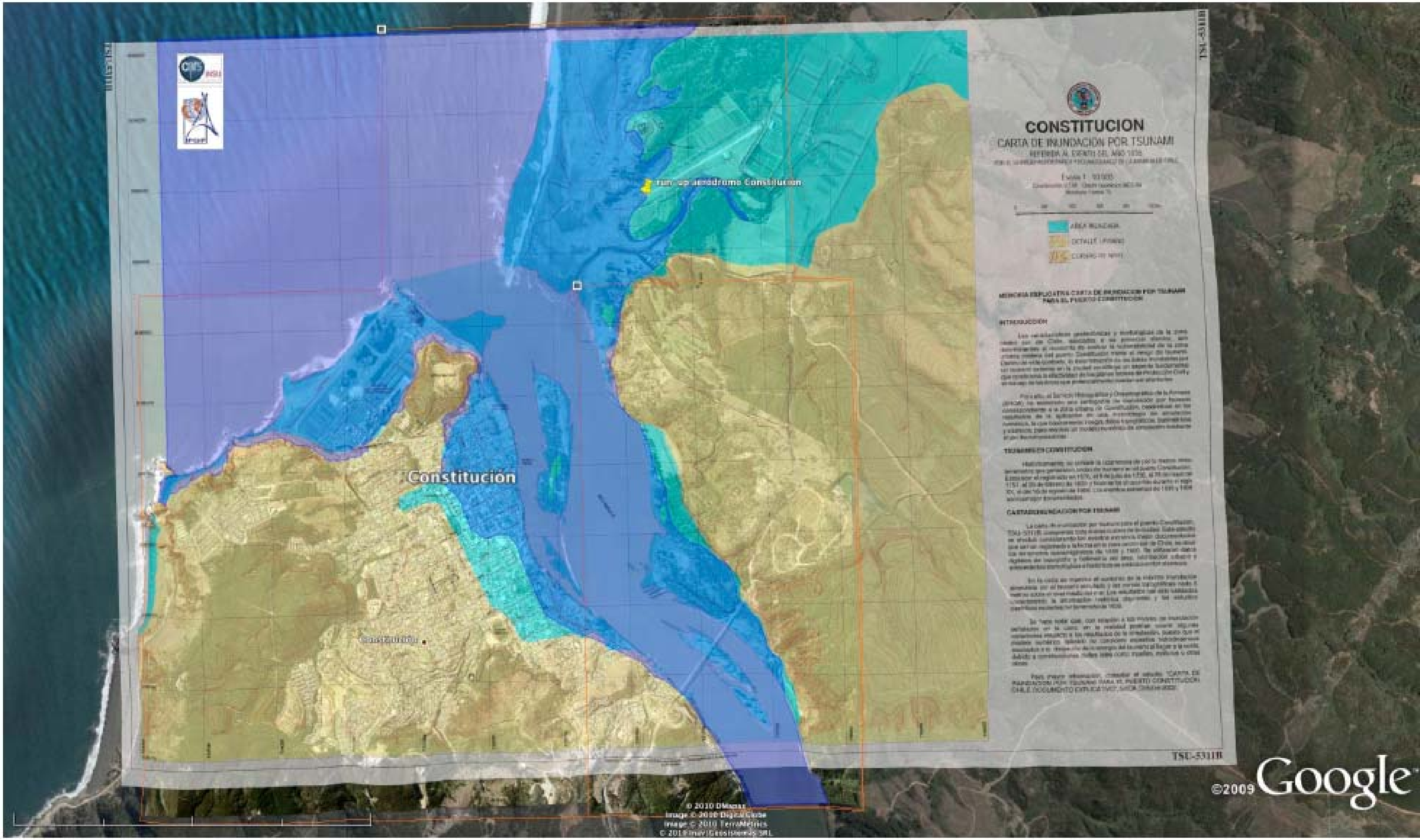
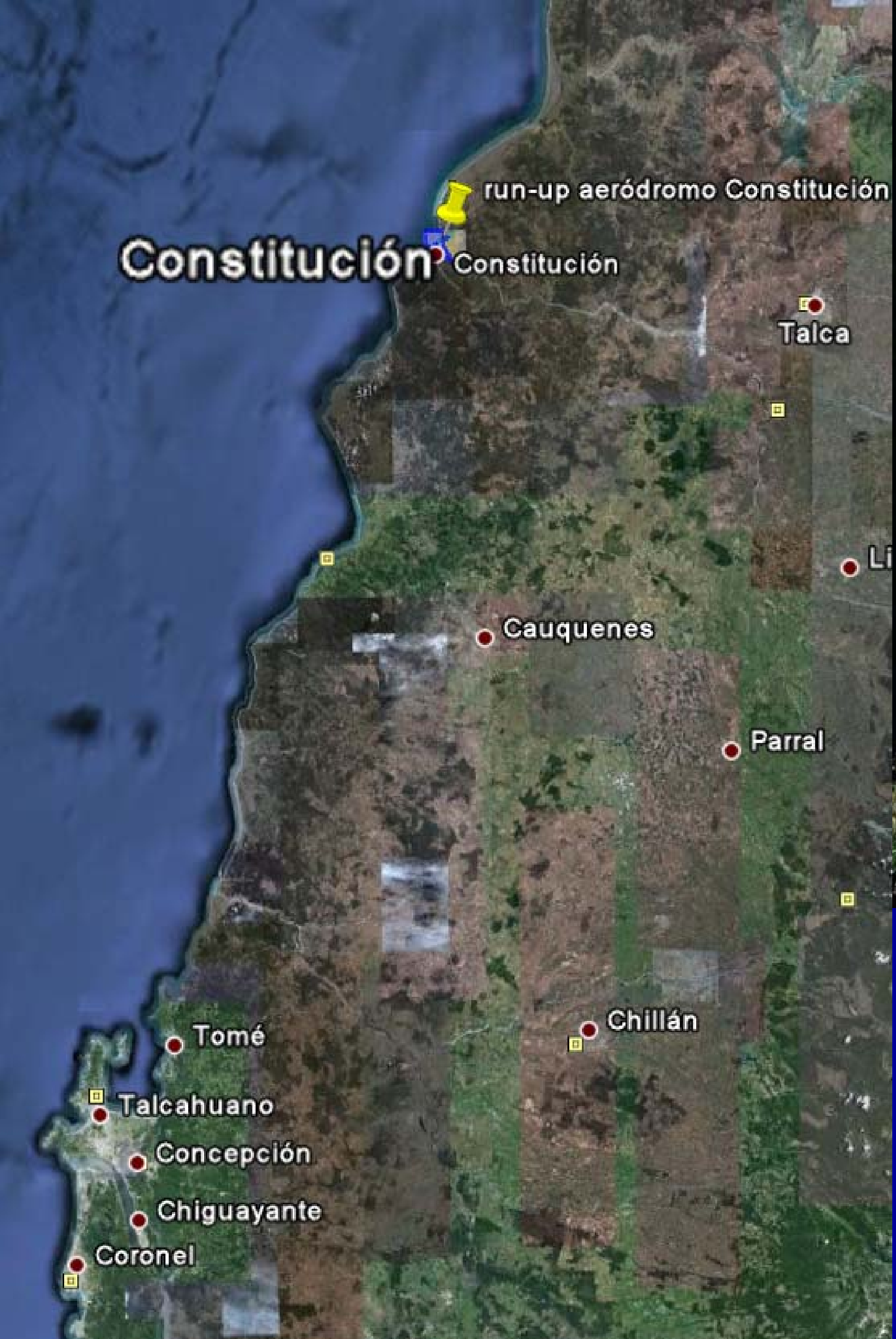
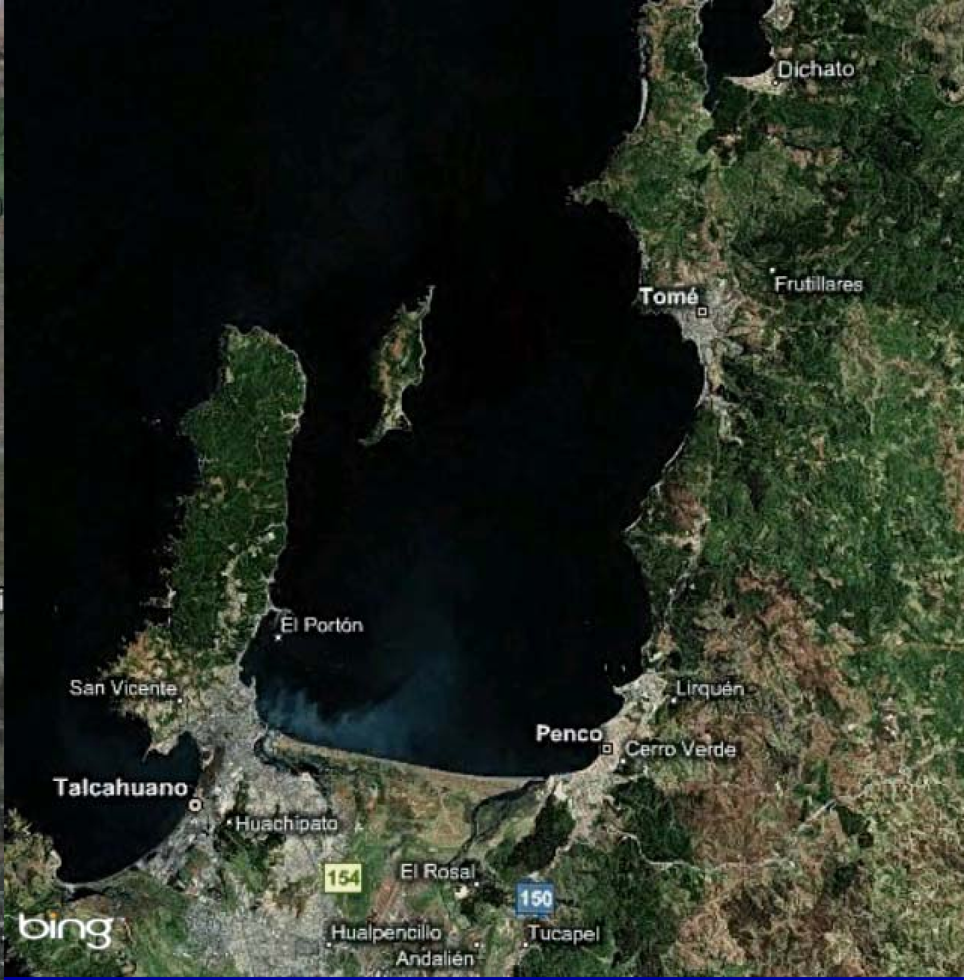

CONSTITUCION
CARTA DE INUNDACION POR TSUNAMI
run-up aerodromo Constitución
Constitución
TSU-5311B
©2009 Google
© 2010 DMapas
Image © 2010 DigitalGlobe
Image © 2010 TerraMetrics

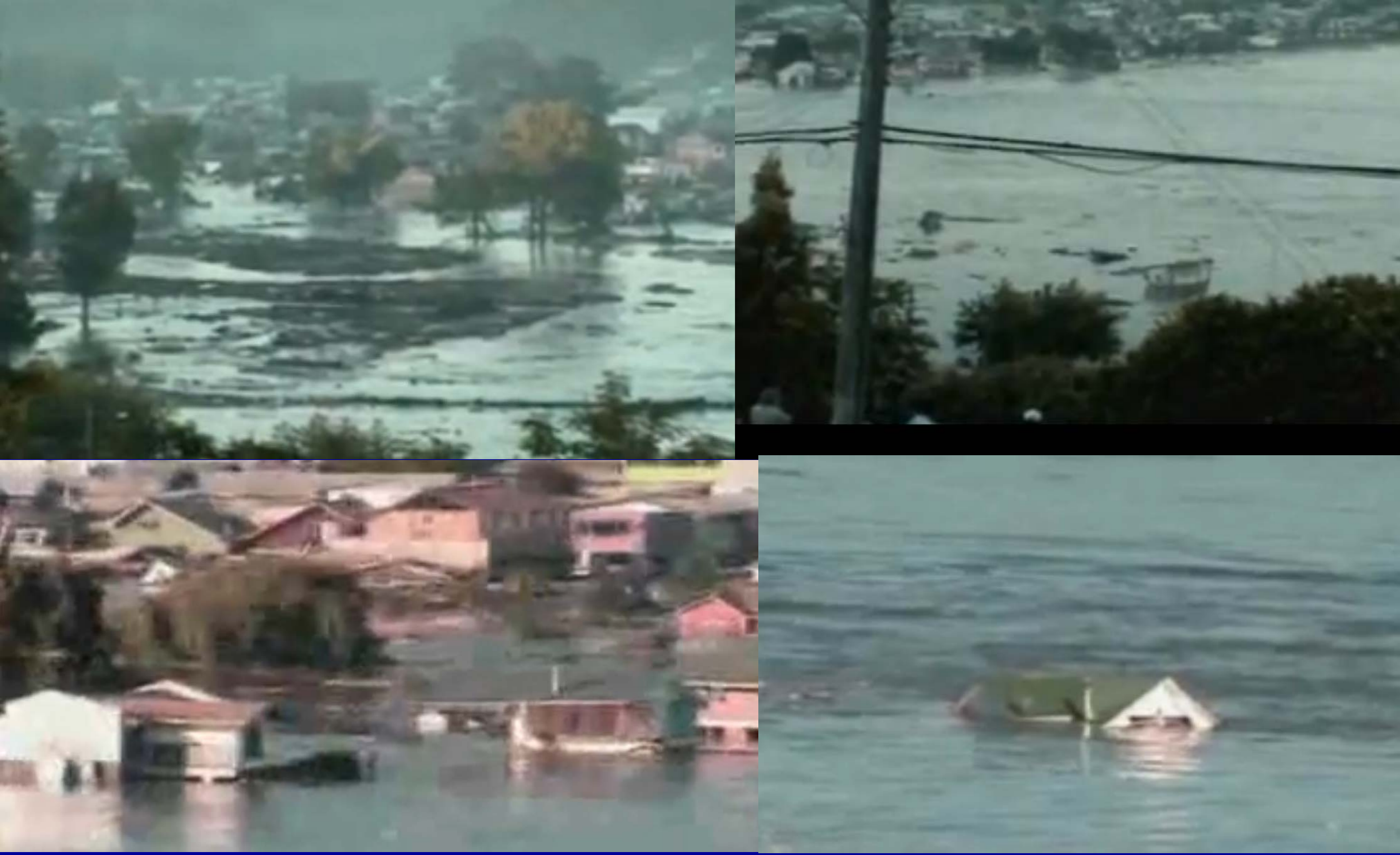
Figure 2 : Areas drowned by 27/02/2010 tsunami (observed run-up in dark blue) overlaid on *Carta de Inundación por Tsunami* established by Servicio Hidrográfico y Oceanográfico de la Armada (SHOA)
Light blue indicates maximum potential tsunami run-up as determined earlier by SHOA





Smaller towns of Dichato and Talcahuano also suffered tremendous damage

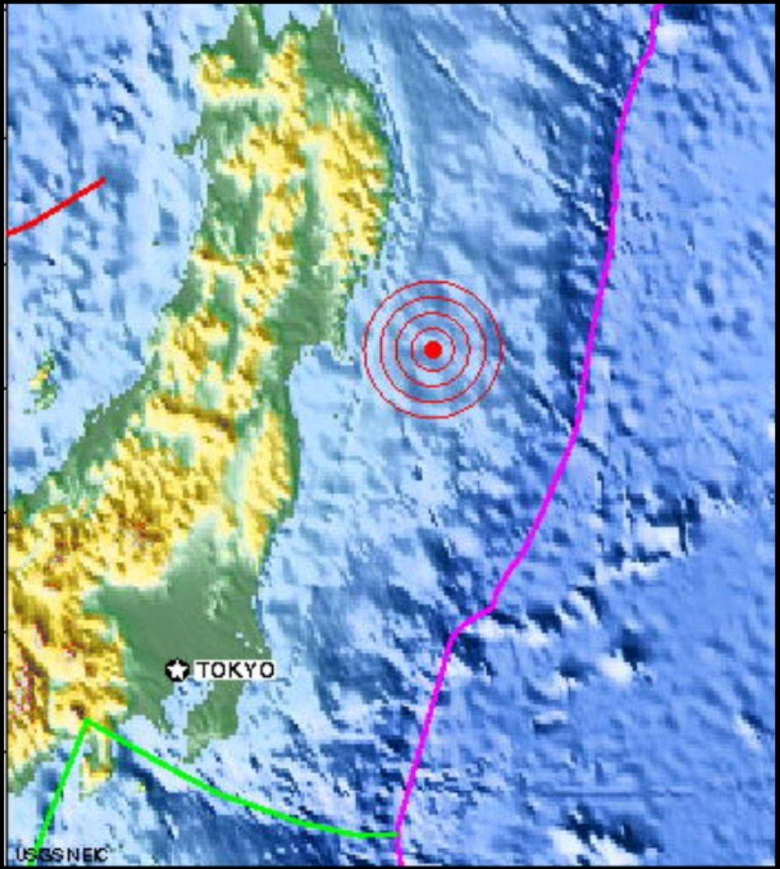
"More than 75 percent of the village is destroyed," said David Merino, a community leader in Dichato on the coast. "After the earthquake there were three waves. The first two were big and didn't do much damage, but the last one almost wiped the village off the map," he said.

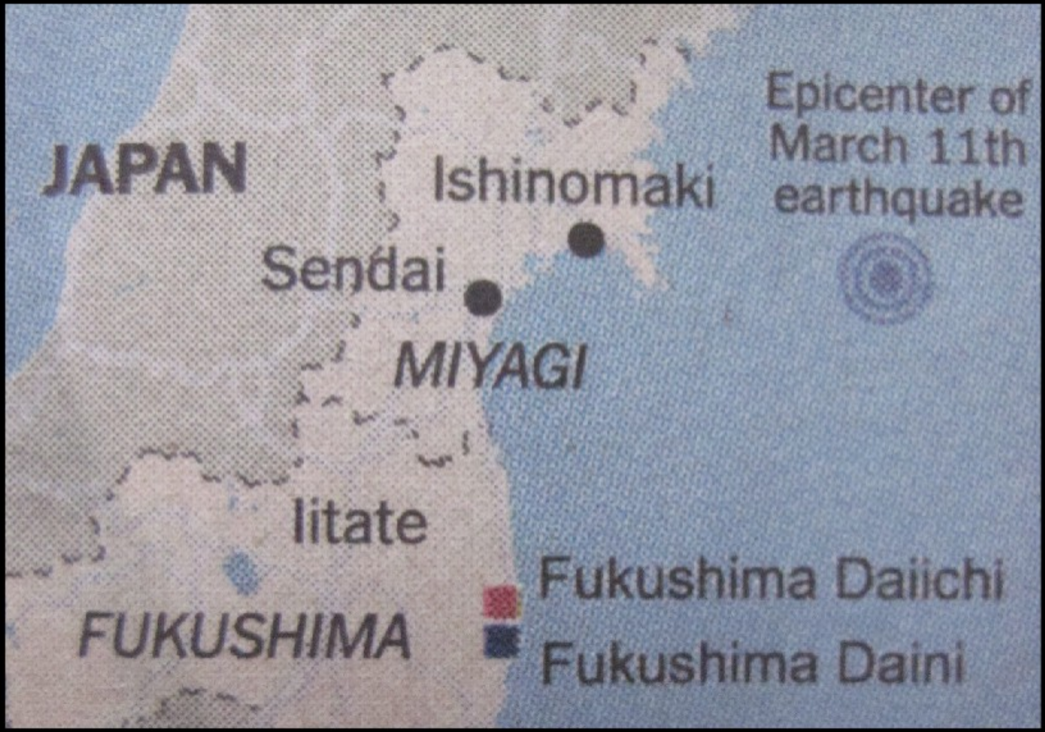


Dichato, Chile

Sendai, March 11, 2011

LOCATION





New York Times

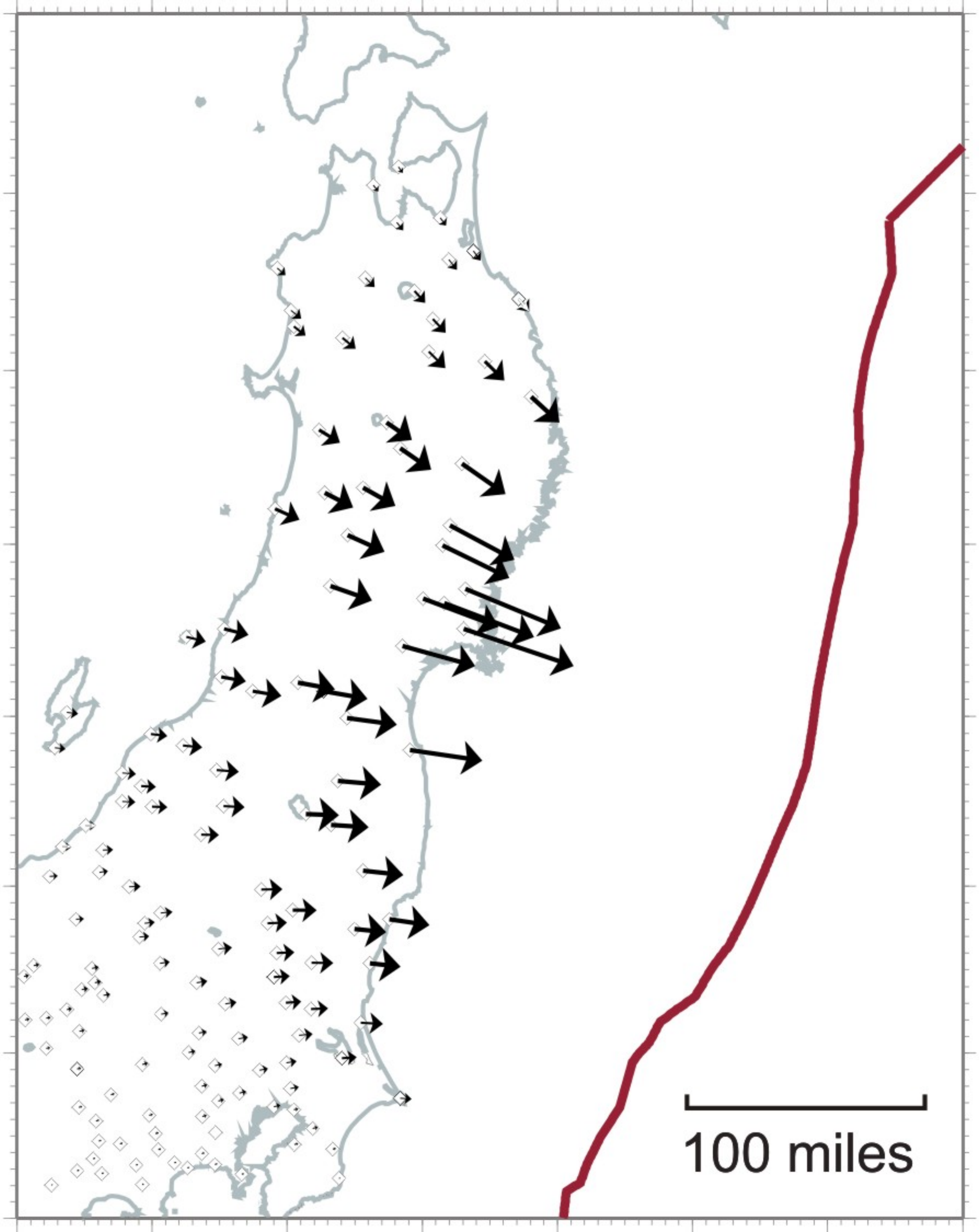
earthquake.usgs.gov/earthquakes/eqinthenews/2011/usc0001xgp/

GPS

Shift happened

→

10 feet

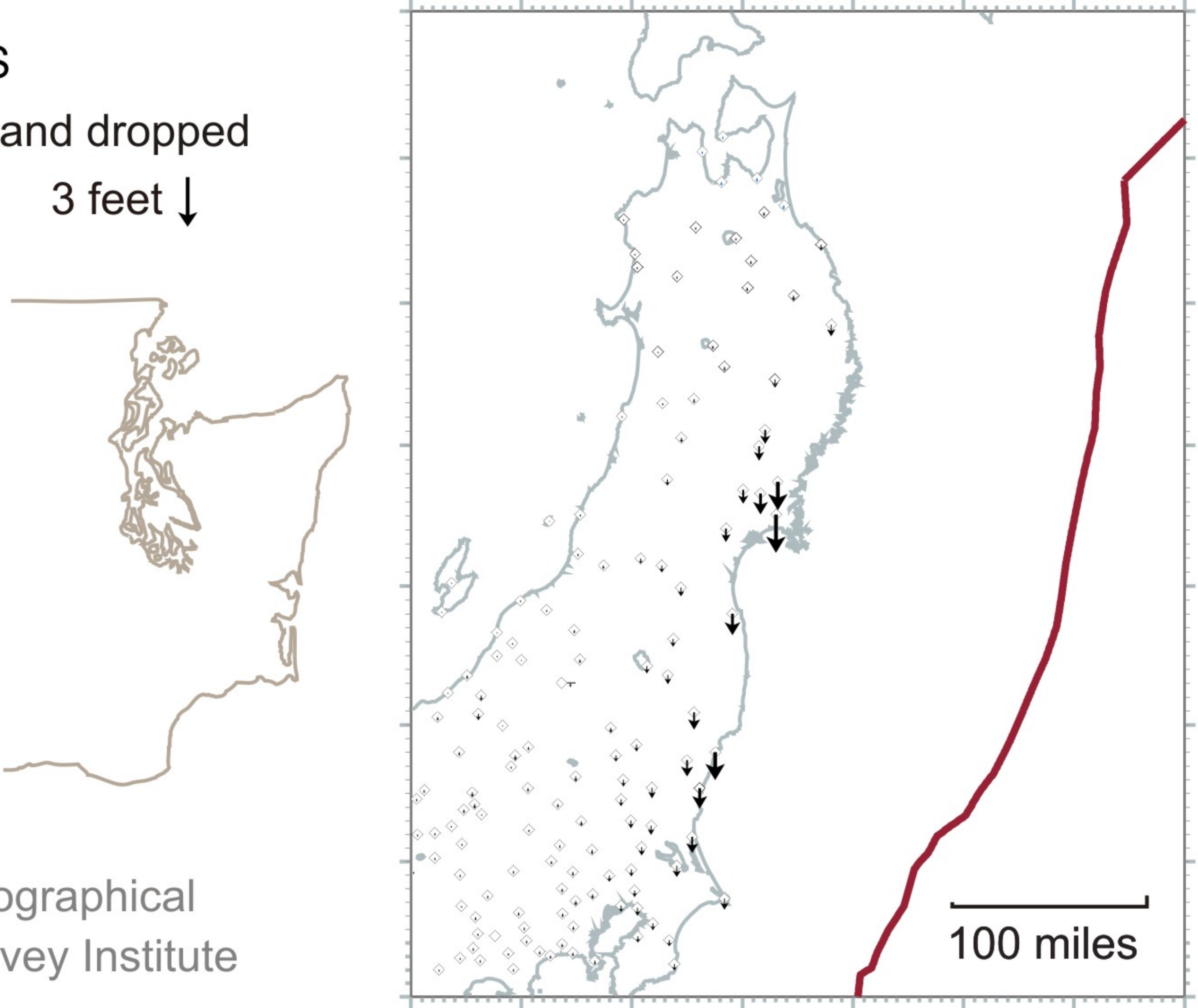


Geographical Survey Institute

GPS

Land dropped

3 feet ↓

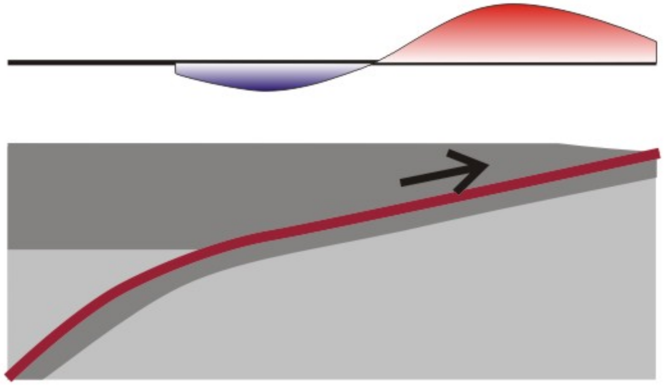


Geographical Survey Institute

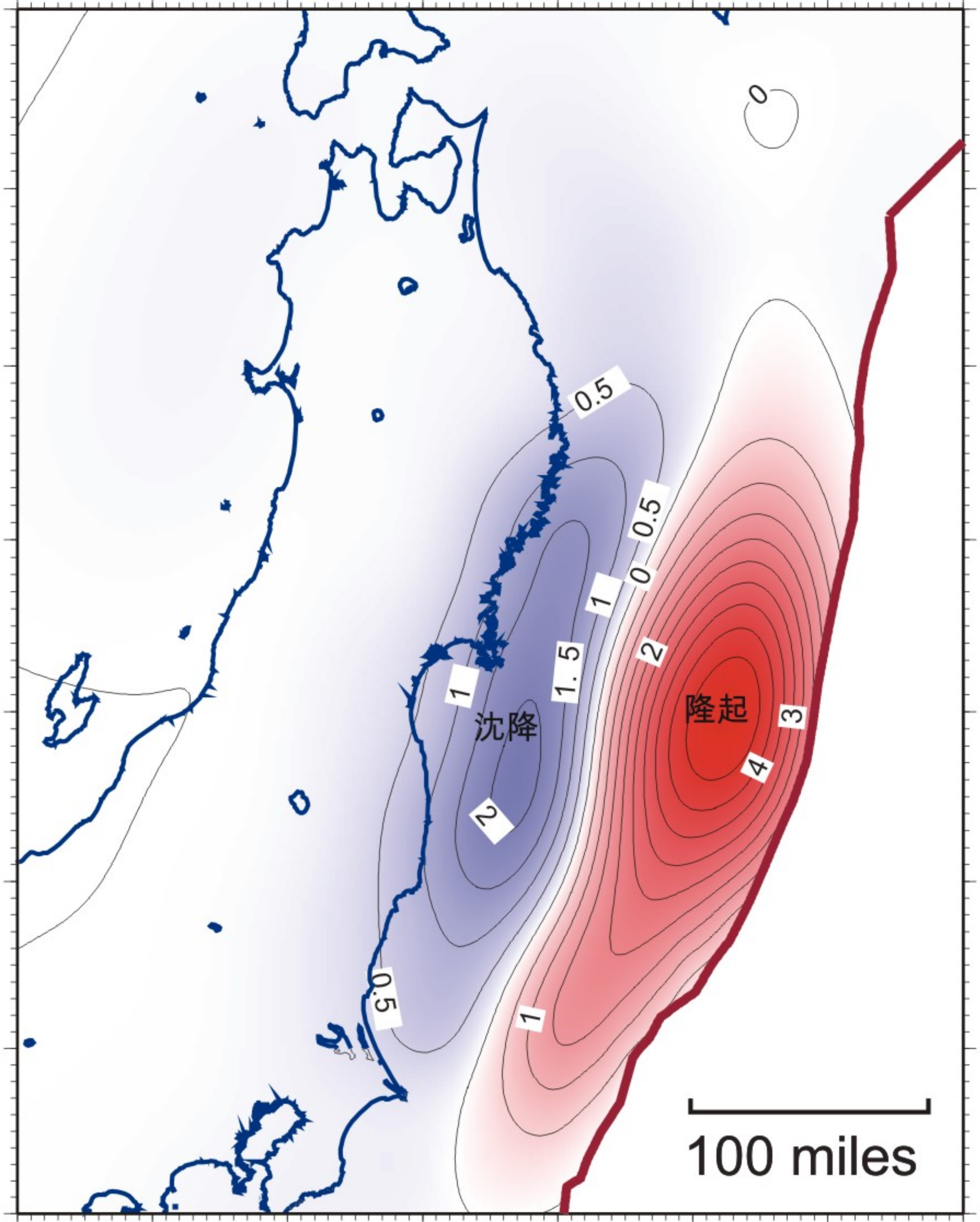
INFERRED TSUNAMI SOURCE

Seafloor moves

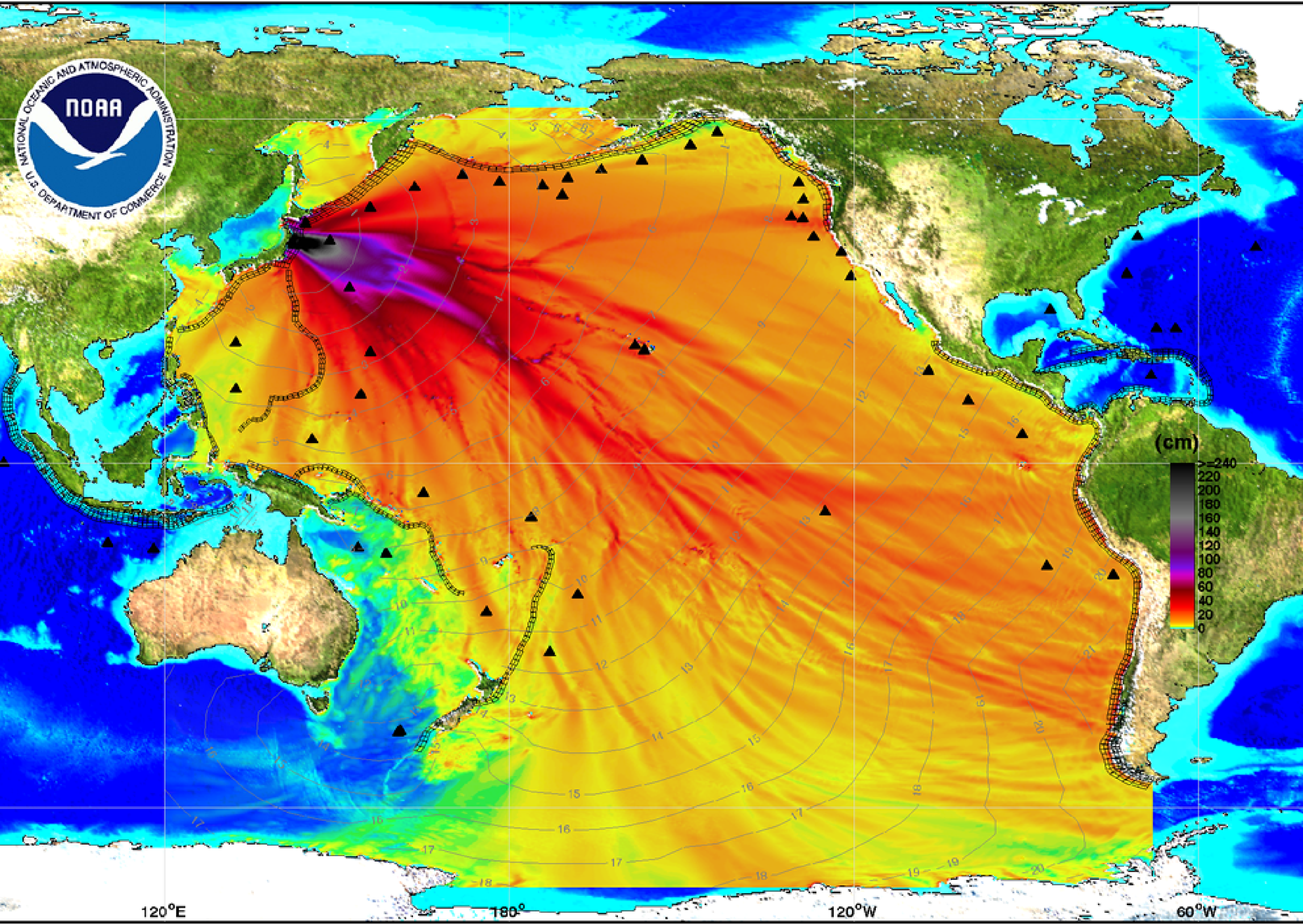
Down Up

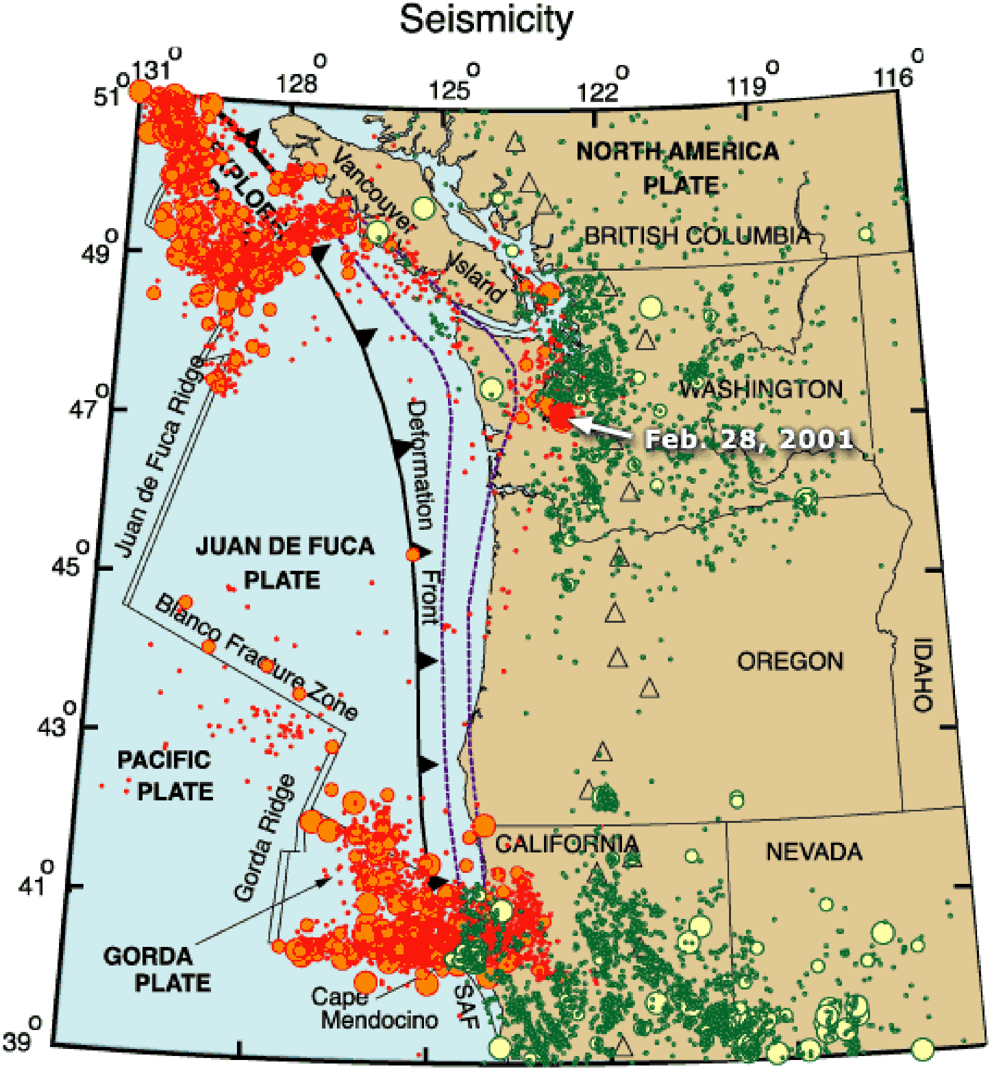


Vertical slice

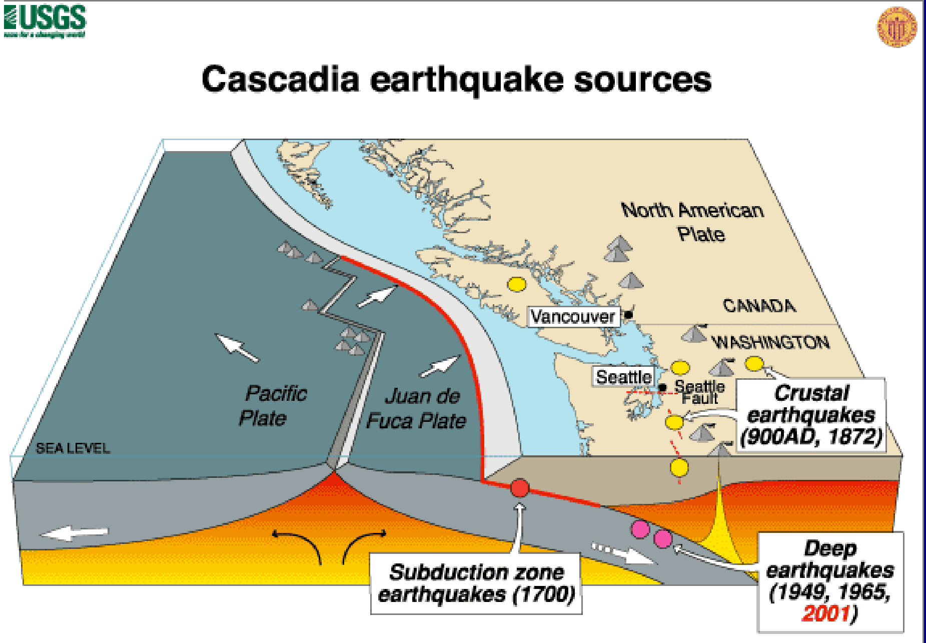


Geographical Survey Institute


NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE
(cm)
>=240
220
200
180
160
140
120
100
80
60
40
20
0
120°E
180°
120°W
60°W



Seismicity



Cascadia earthquake sources

	Source	Affected area	Max. Size	Recurrence
🔴	Subduction Zone	W.WA, OR, CA	M 9	500-600 yr
●	Deep Juan de Fuca plate	W.WA, OR,	M 7+	30-50 yr
🟡	Crustal faults	WA, OR, CA	M 7+	Hundreds of yr?

Washington has a subduction zone too, but it has been quiet since European settlement.

SUNDA TRENCH

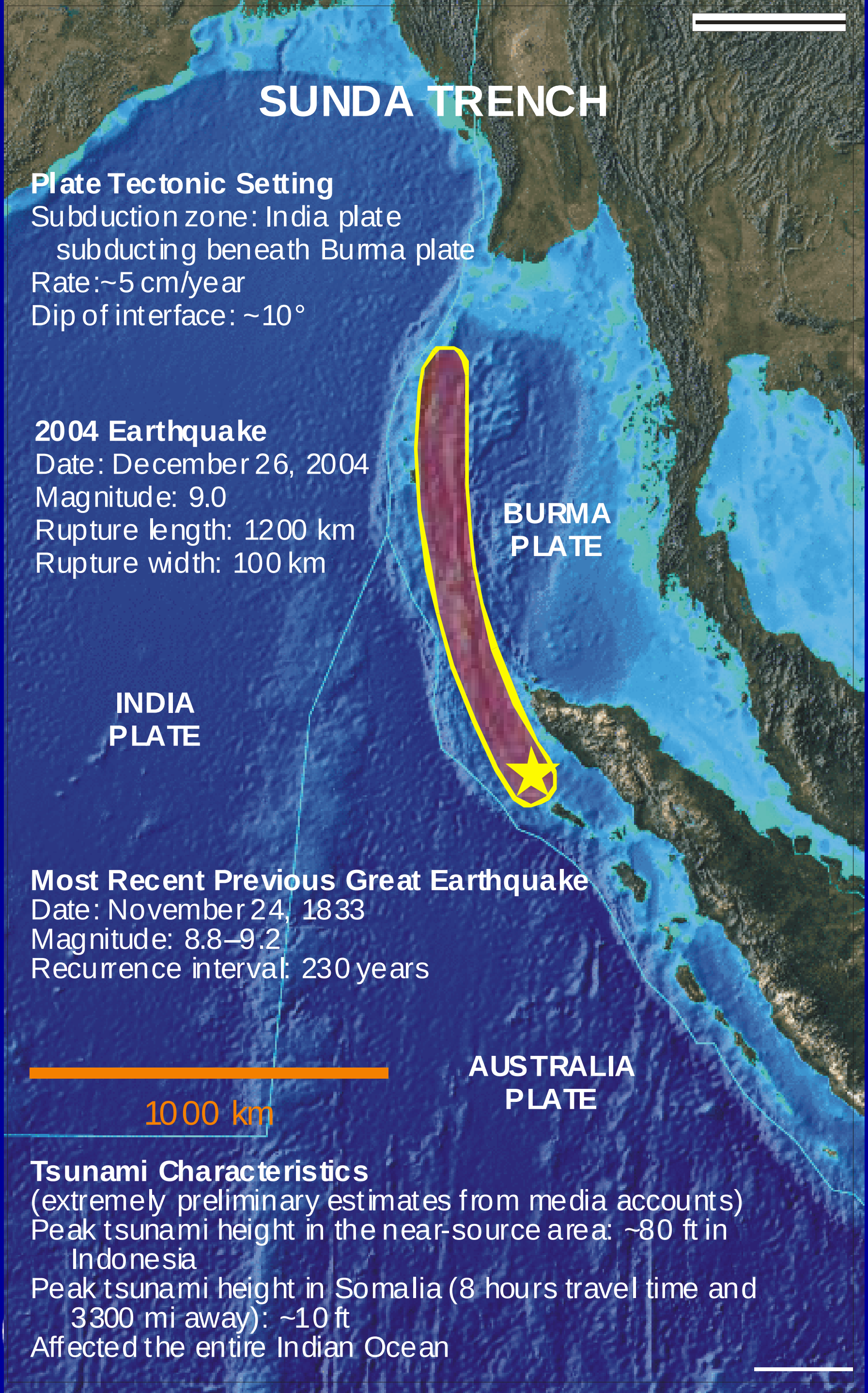


Plate Tectonic Setting
Subduction zone: India plate subducting beneath Burma plate
Rate: ~5 cm/year
Dip of interface: ~10°

2004 Earthquake
Date: December 26, 2004
Magnitude: 9.0
Rupture length: 1200 km
Rupture width: 100 km

Most Recent Previous Great Earthquake
Date: November 24, 1833
Magnitude: 8.8–9.2
Recurrence interval: 230 years

Tsunami Characteristics
(extremely preliminary estimates from media accounts)
Peak tsunami height in the near-source area: ~80 ft in Indonesia
Peak tsunami height in Somalia (8 hours travel time and 3300 mi away): ~10 ft
Affected the entire Indian Ocean

CASCADIA SUBDUCTION ZONE

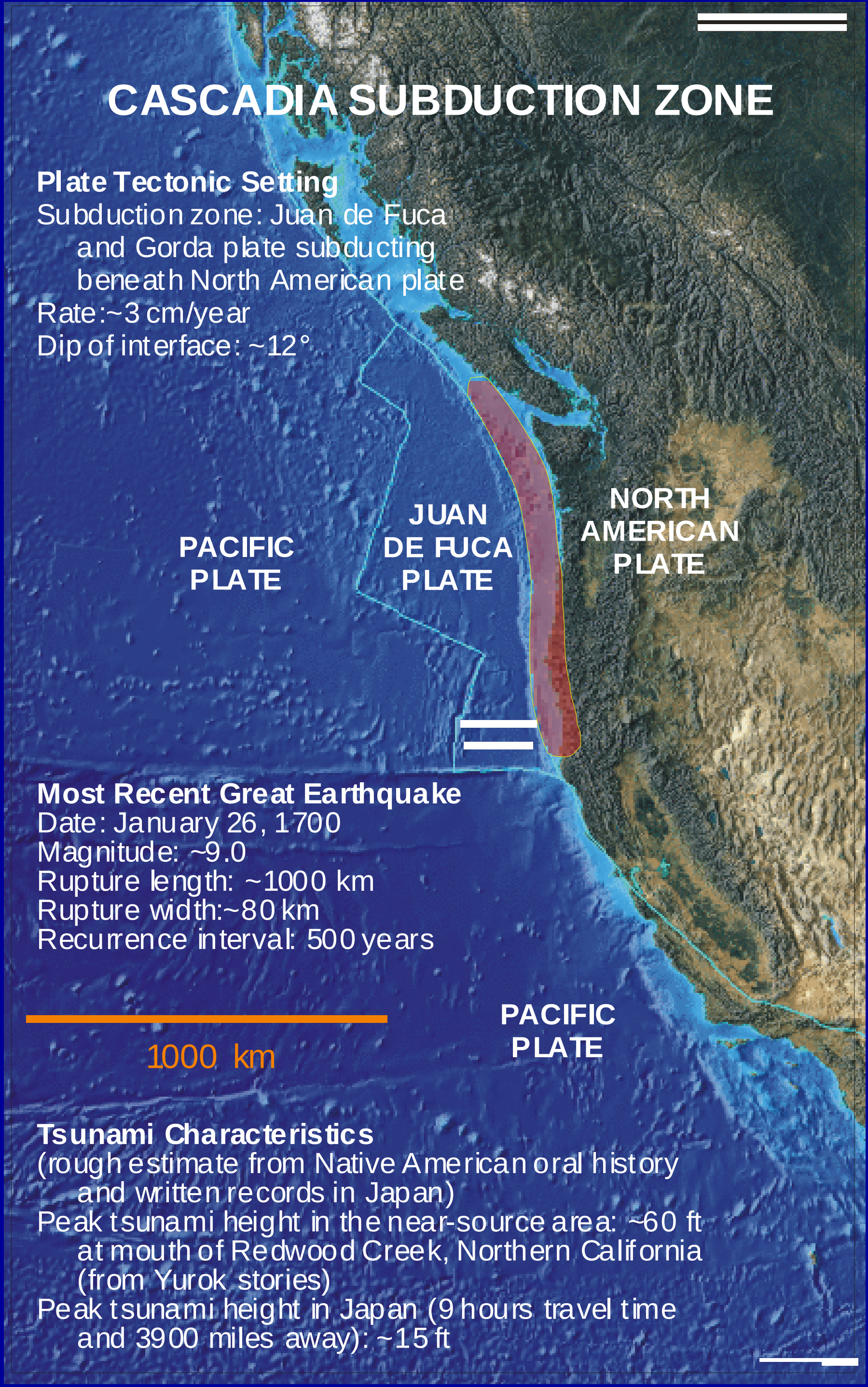
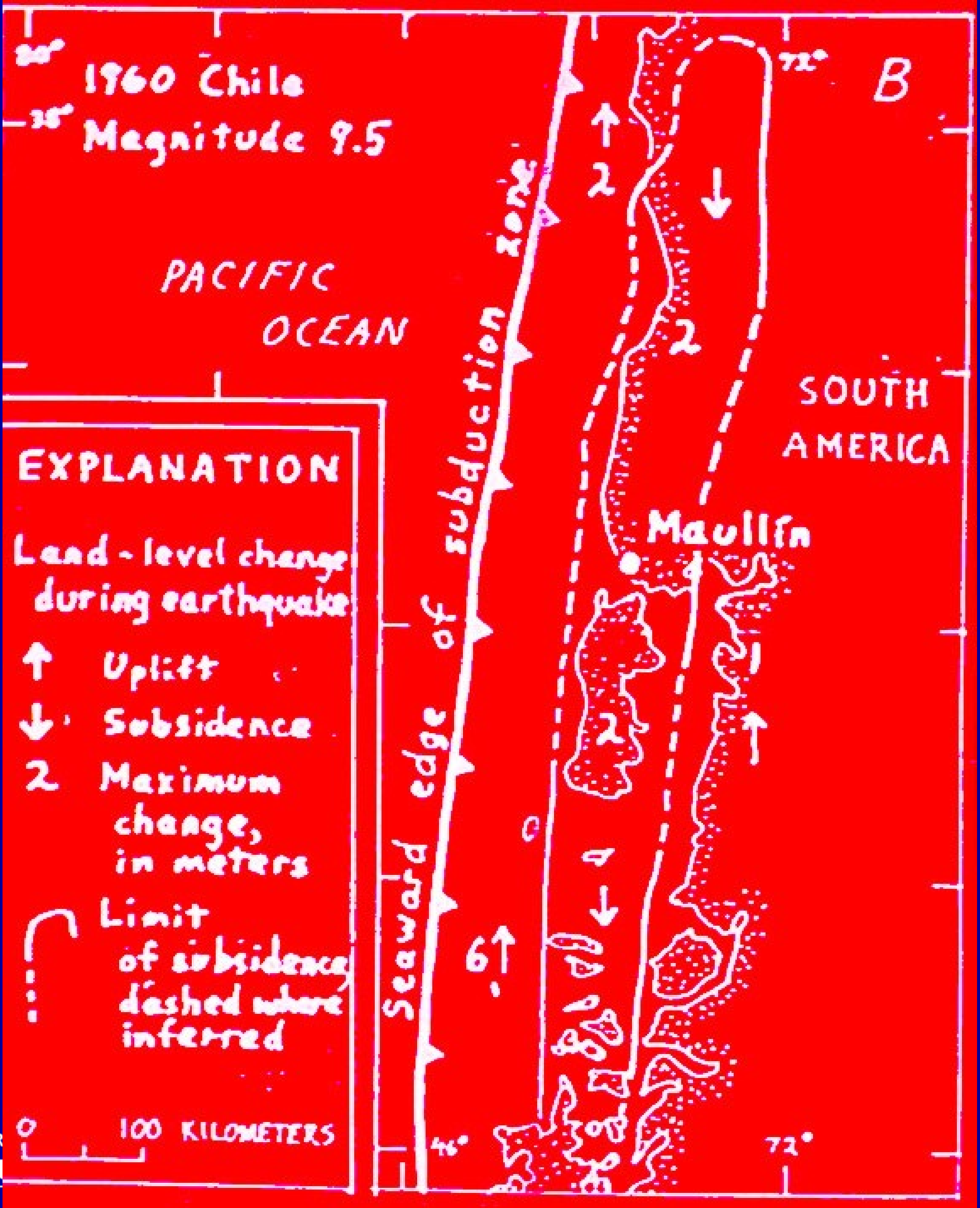


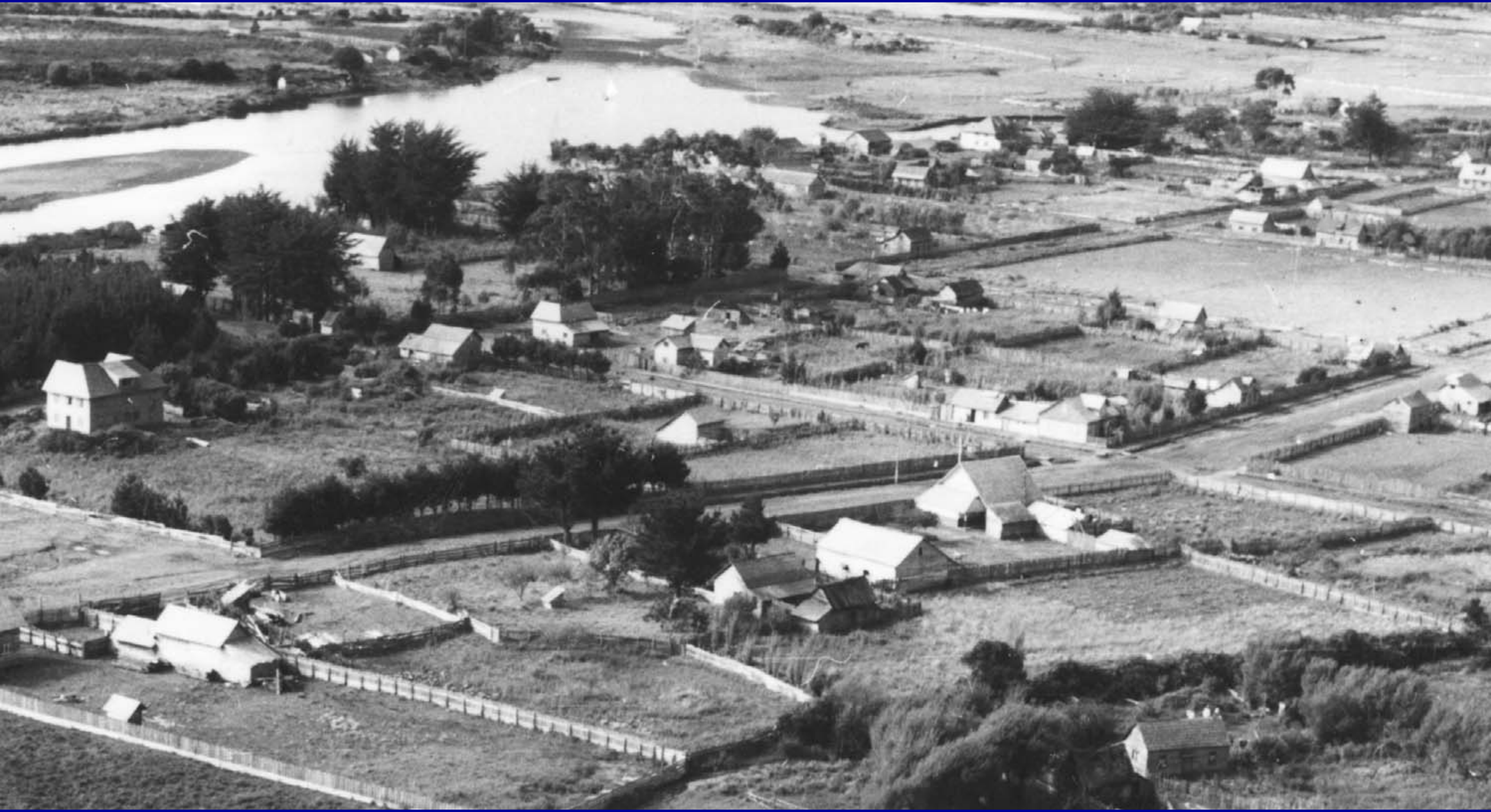
Plate Tectonic Setting
Subduction zone: Juan de Fuca and Gorda plate subducting beneath North American plate
Rate: ~3 cm/year
Dip of interface: ~12°

Most Recent Great Earthquake
Date: January 26, 1700
Magnitude: ~9.0
Rupture length: ~1000 km
Rupture width: ~80 km
Recurrence interval: 500 years

Tsunami Characteristics
(rough estimate from Native American oral history and written records in Japan)
Peak tsunami height in the near-source area: ~60 ft at mouth of Redwood Creek, Northern California (from Yurok stories)
Peak tsunami height in Japan (9 hours travel time and 3900 miles away): ~15 ft


30°
35°
1960 Chile
Magnitude 9.5
72°
B
PACIFIC
OCEAN
SOUTH
AMERICA
Seaward edge of subduction zone
2
2
2
1
6
0
Maullín
46°
72°
EXPLANATION
Land-level change during earthquake
↑ Uplift
↓ Subsidence
2 Maximum change, in meters
Limit of subsidence, dashed where inferred
0 100 KILOMETERS

Queule Chile--Before



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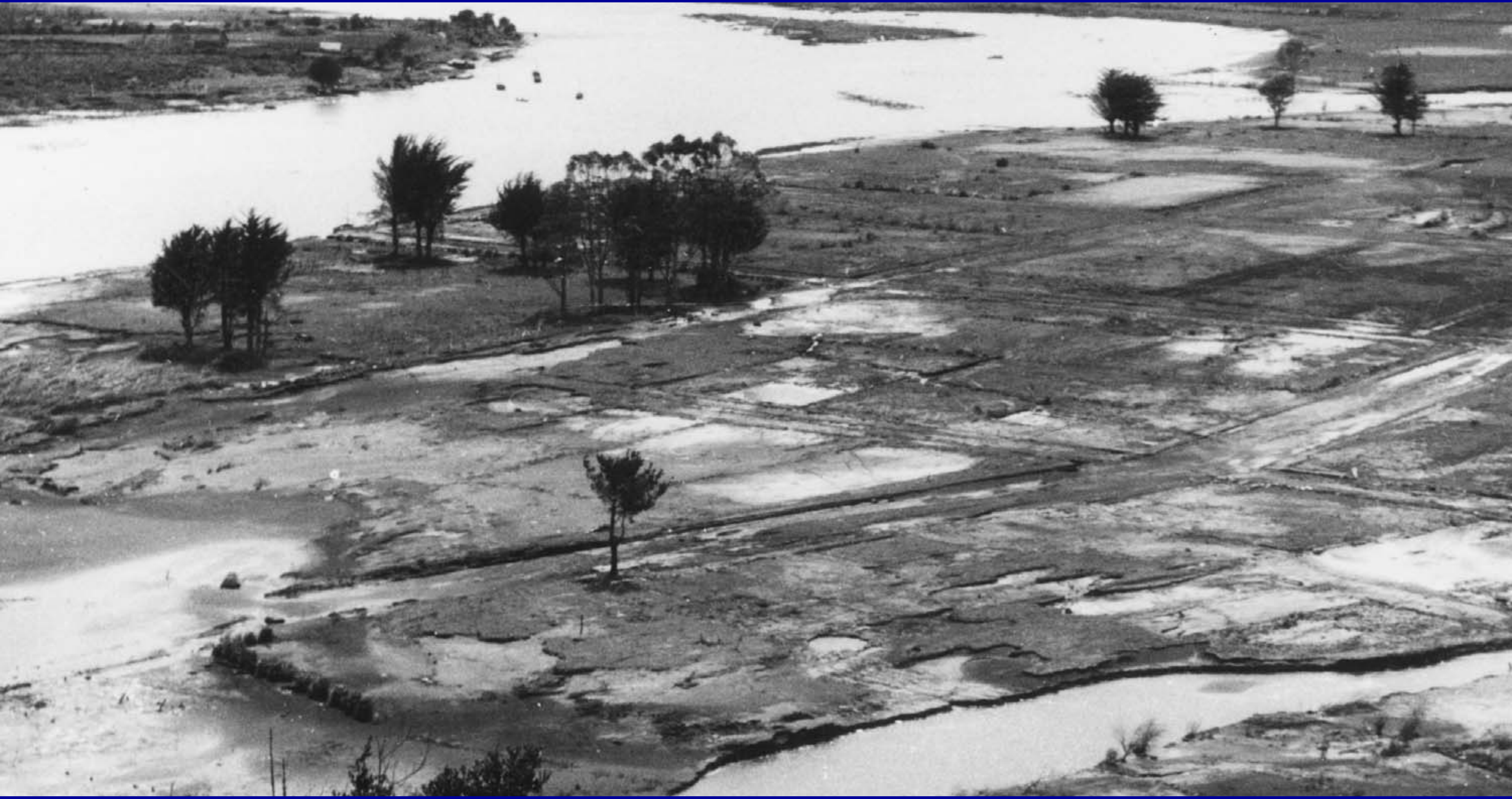
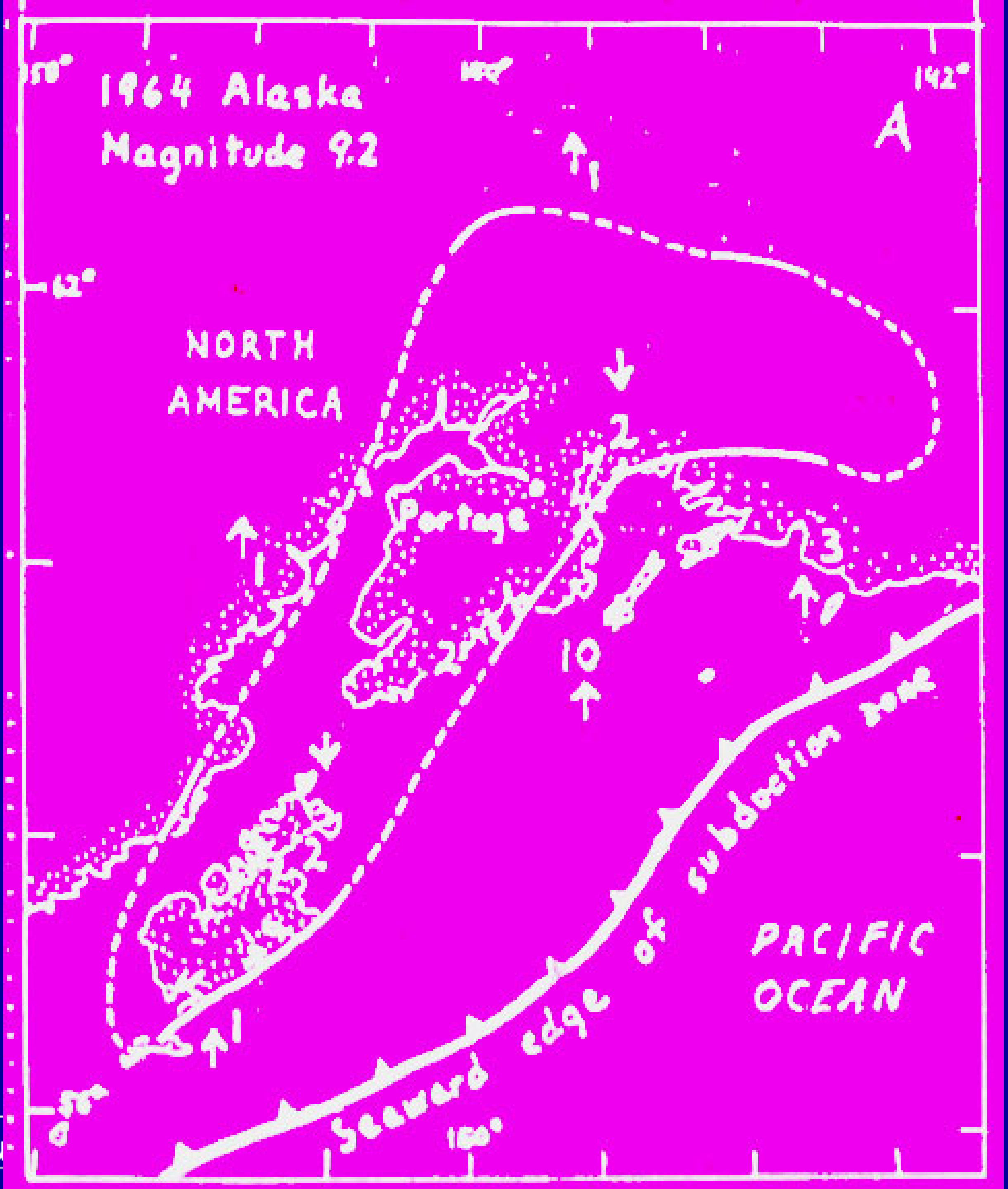
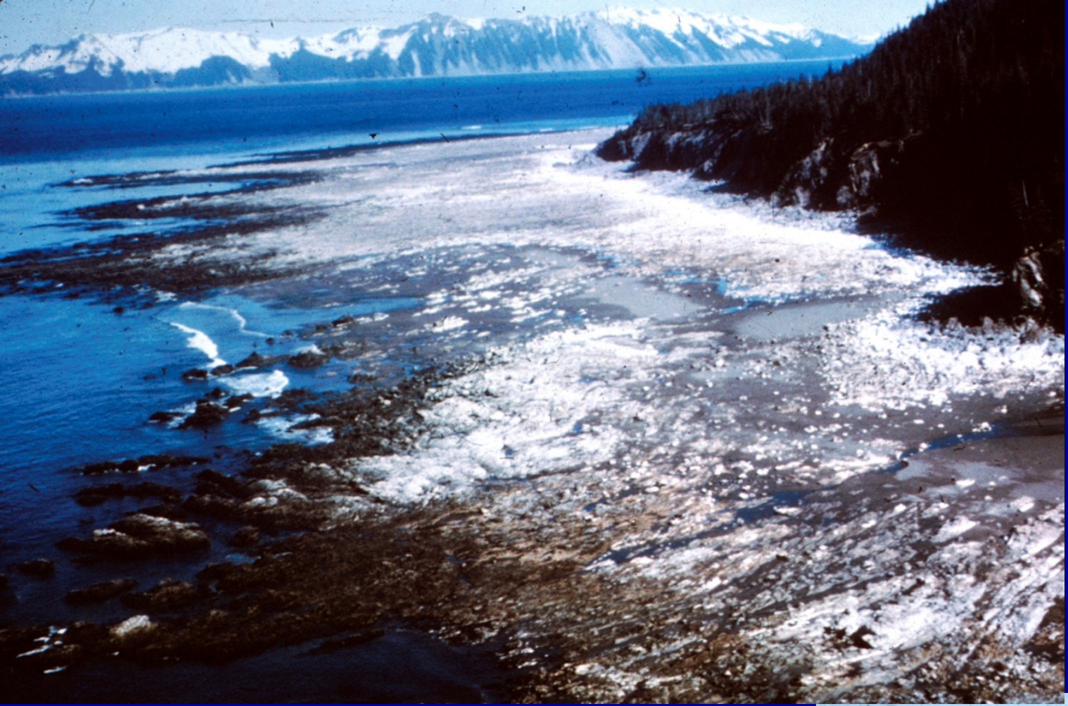
Natural Resources

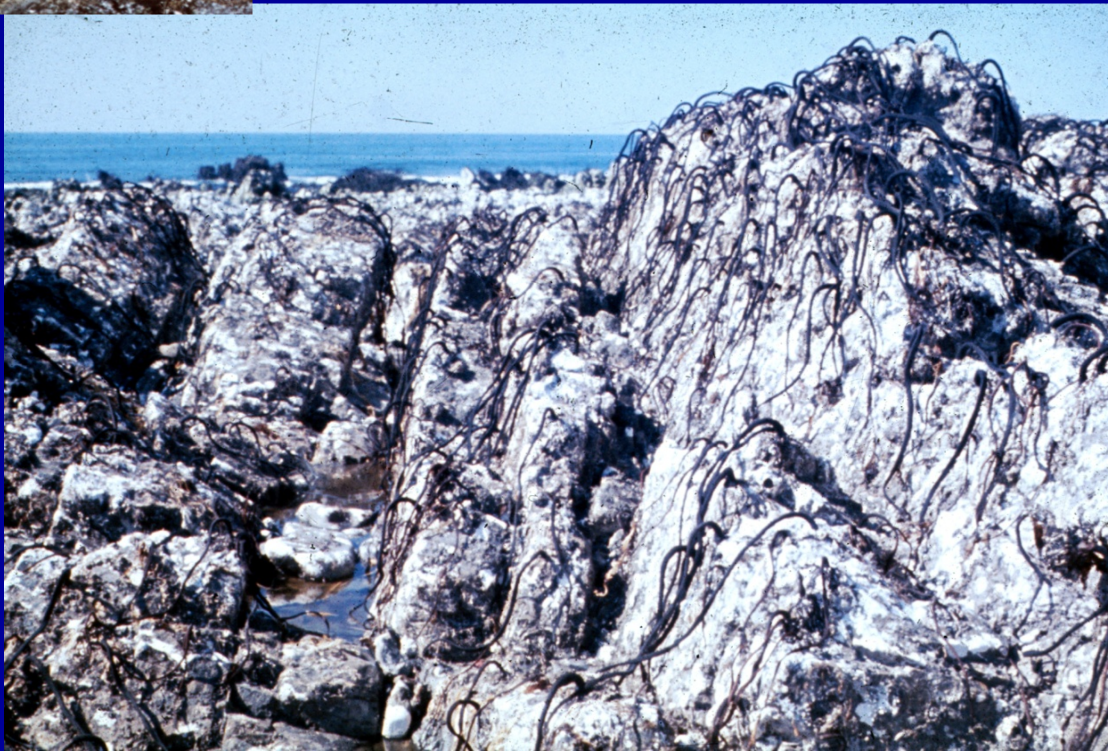
Queule Chile--After




1964 Alaska
Magnitude 9.2
A
142°
62°
NORTH AMERICA
Portage
1
2
3
10
1
1
PACIFIC OCEAN
Seaward edge of subduction zone



This former wave-cut platform in Prince William Sound was uplifted nearly 33 feet in the earthquake in 1964, stranding seaweed high above the beach.



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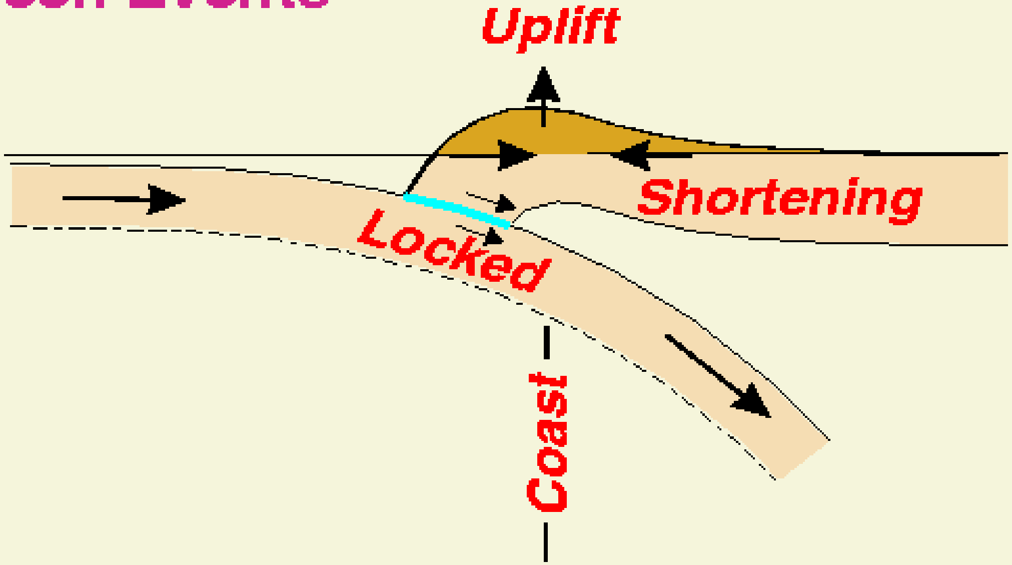
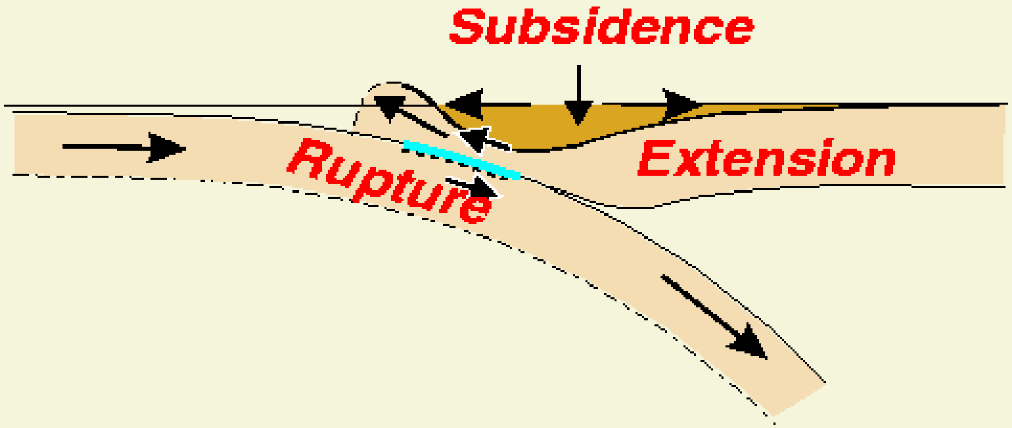
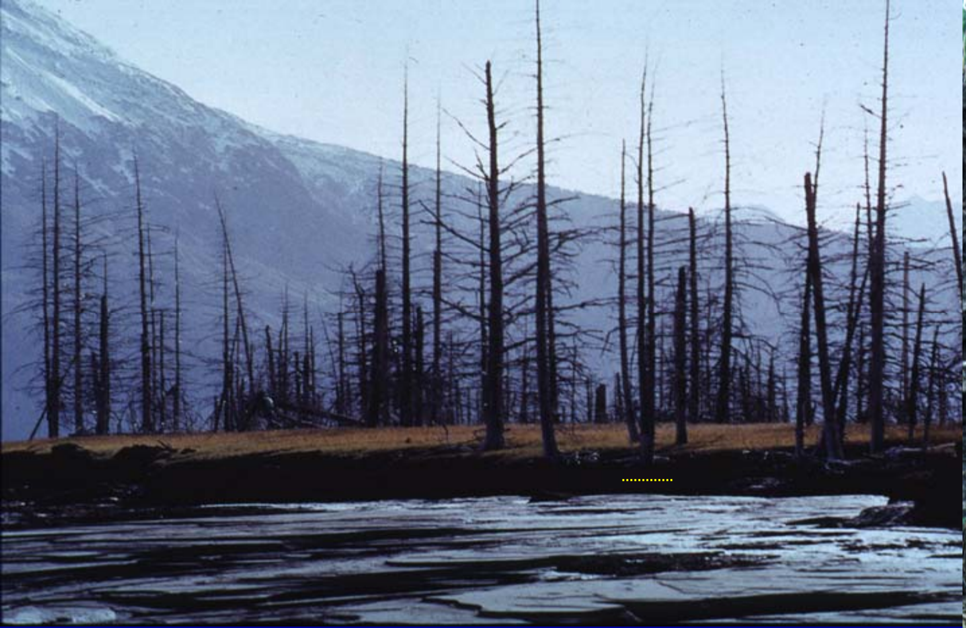
Between Events

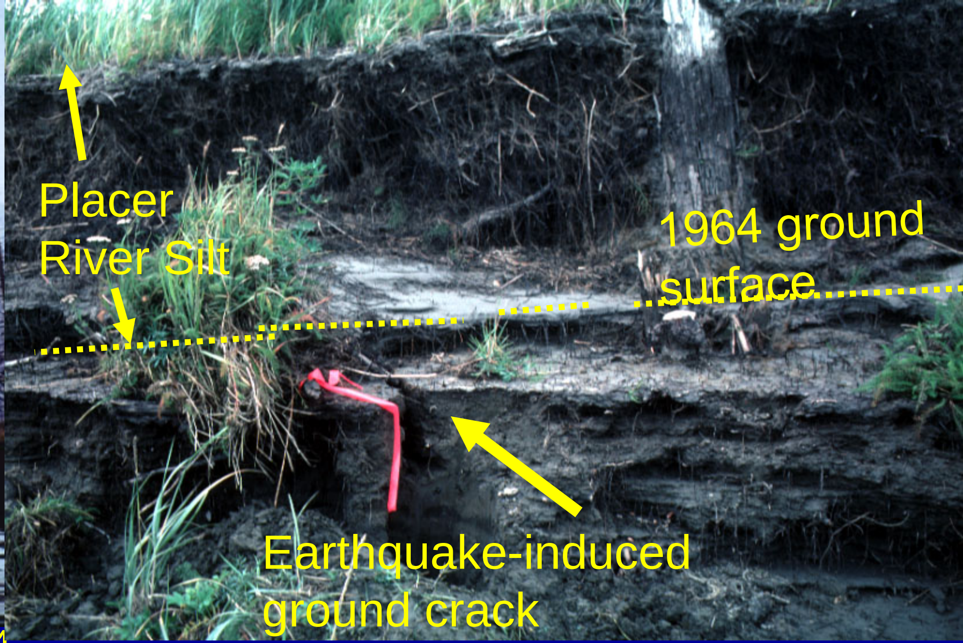


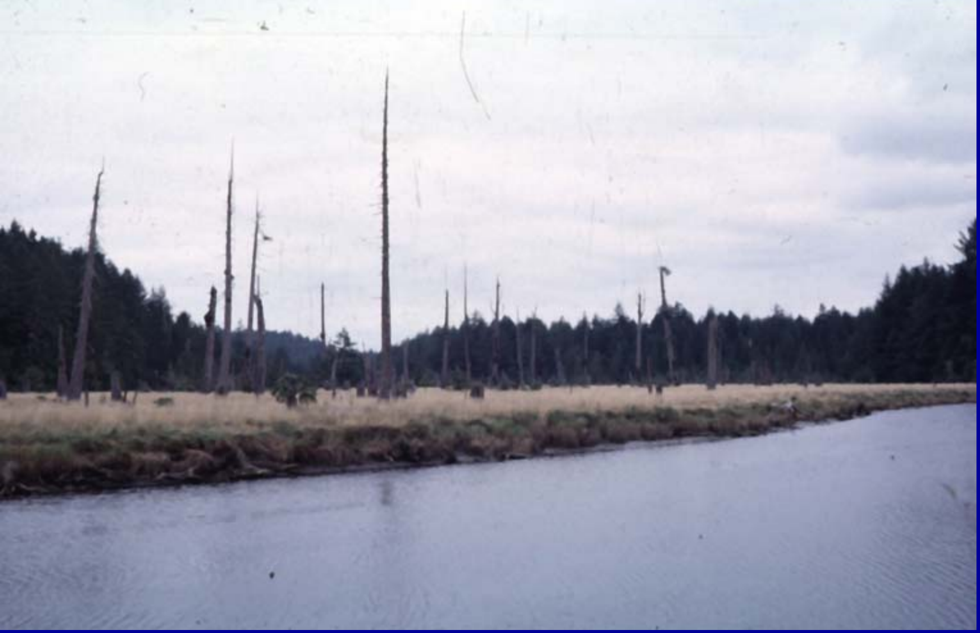
Earthquake



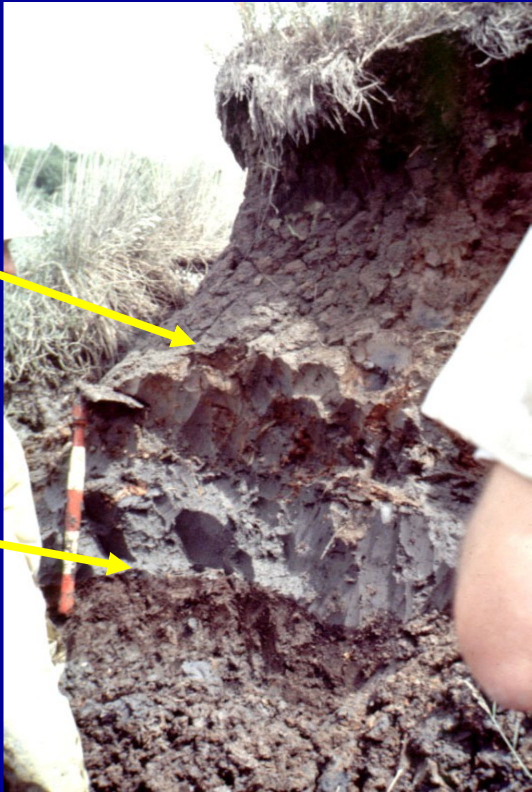


Drowned forest in Girdwood, Alaska, killed in 1964

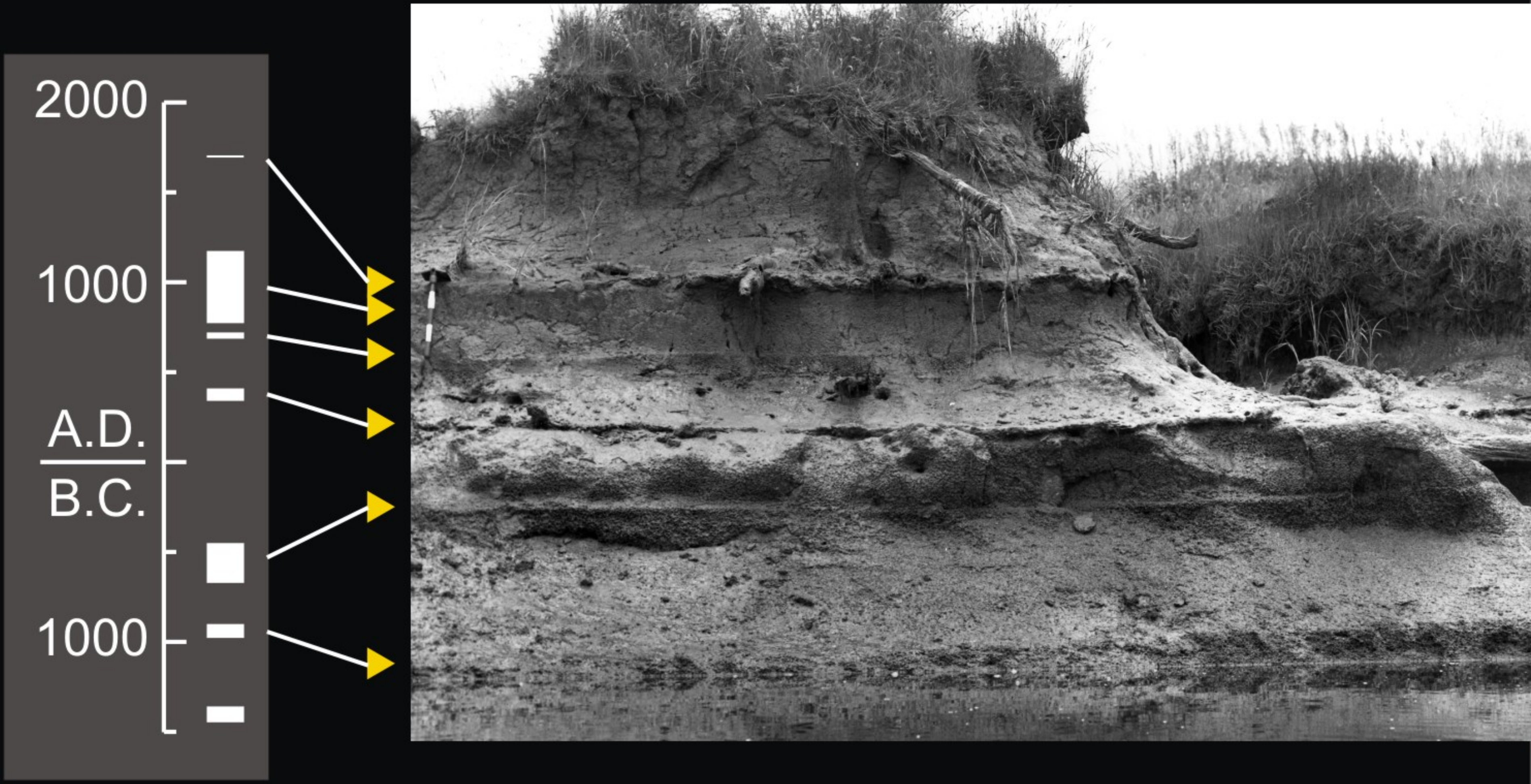




Drowned forest along the Copalis River, Washington, killed in A.D. 1700



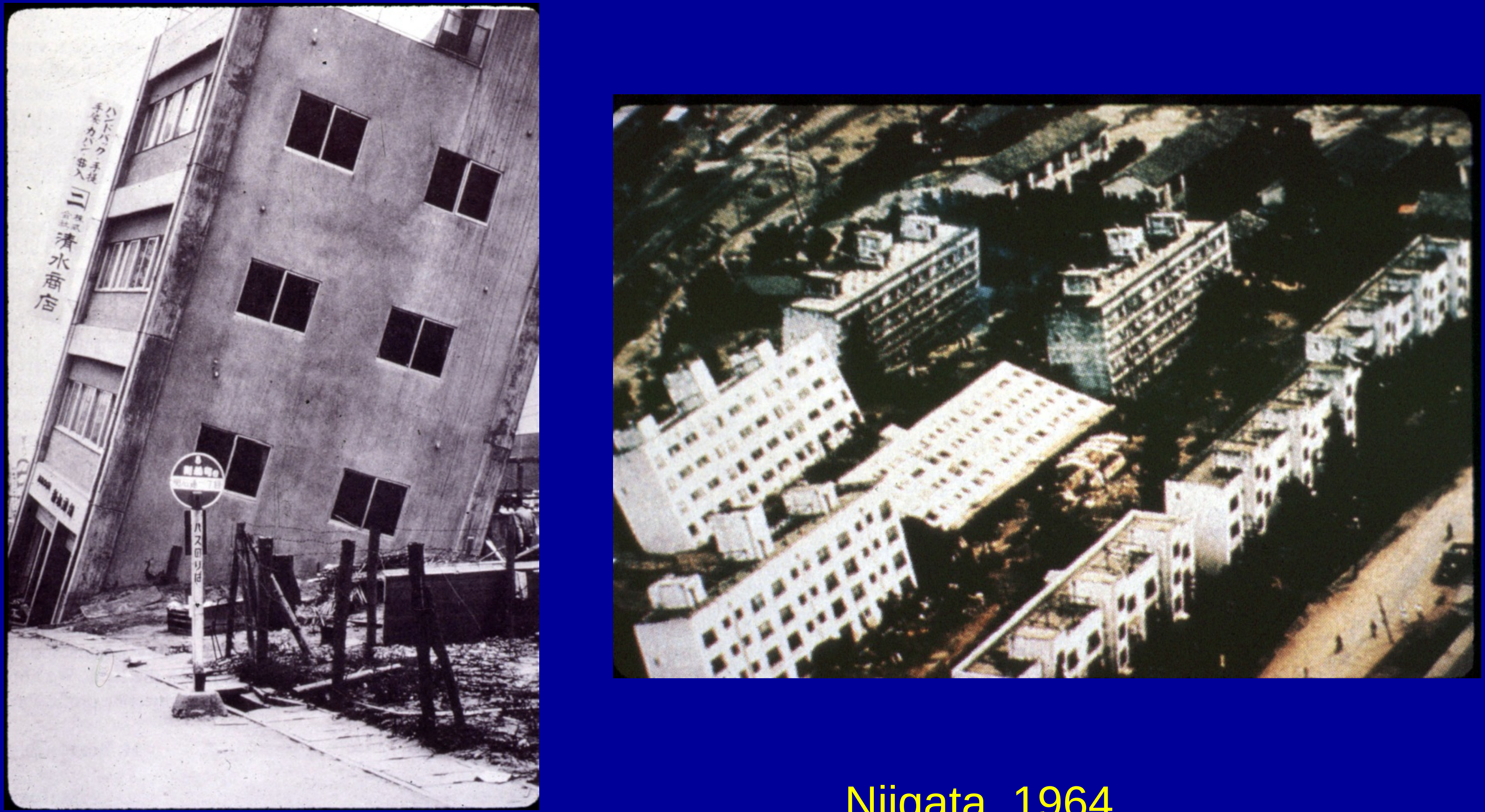
Timeline



Age ranges at >95-percent confidence
Grays Harbor, Willapa Bay, Columbia River

From Brian Atwater

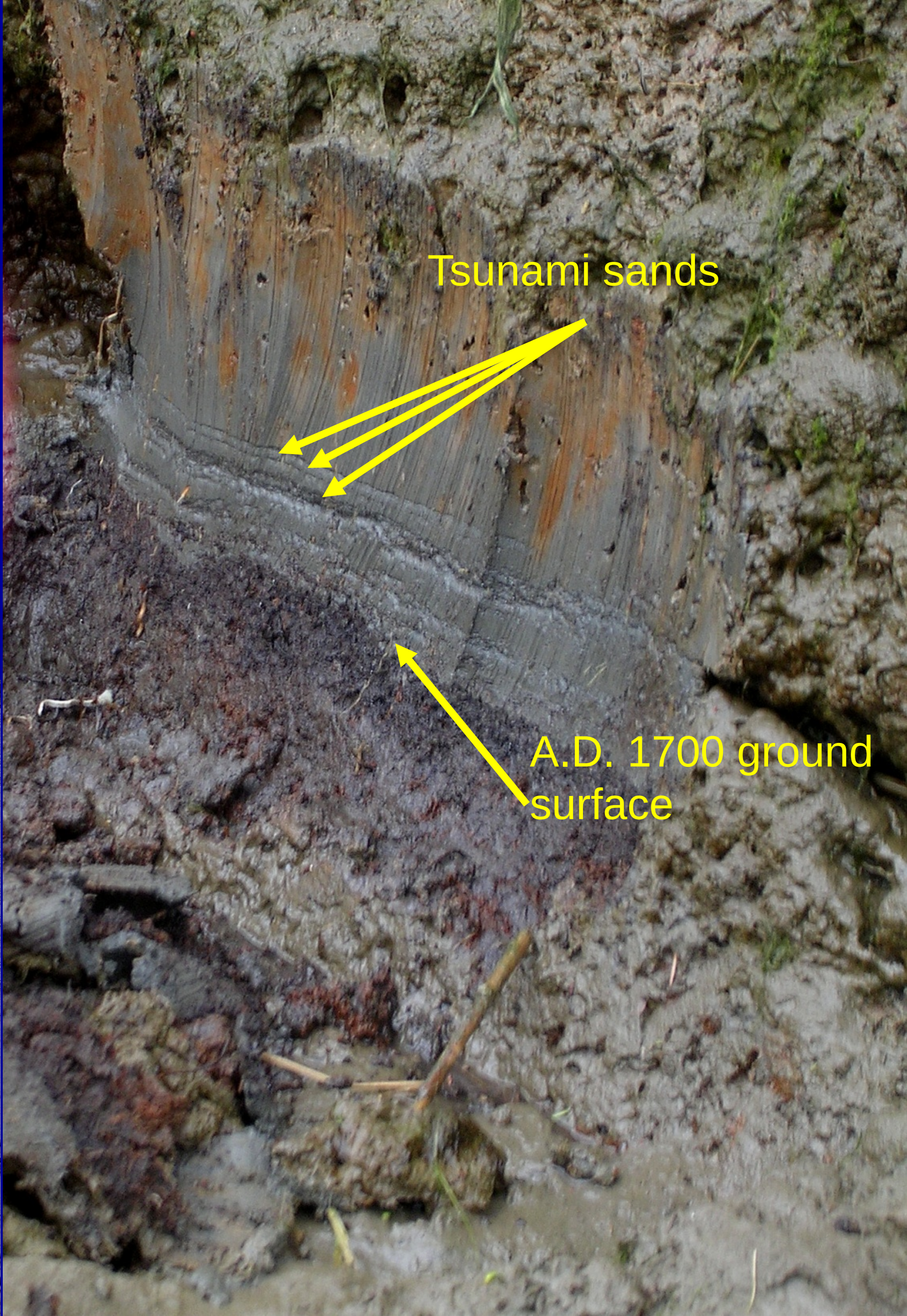
The long duration also enhances the occurrence of liquefaction in susceptible soils



Niigata, 1964

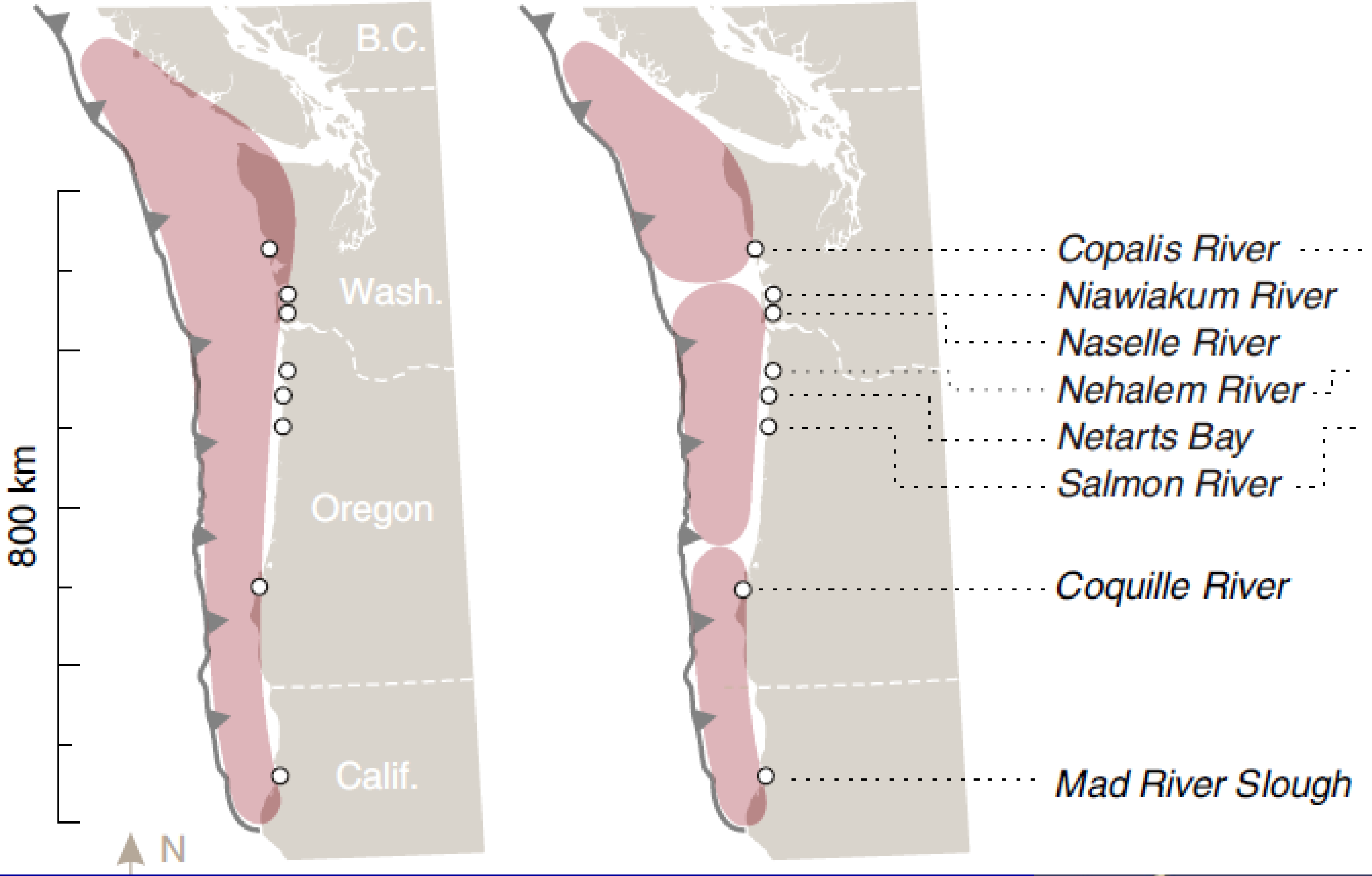
Brent Kooi
Chiba City, Japan
CN
iRep

Right, subsided marsh along the Niawiakum River, southwest Washington. Below, note pitfalls of working in tidal marshes.



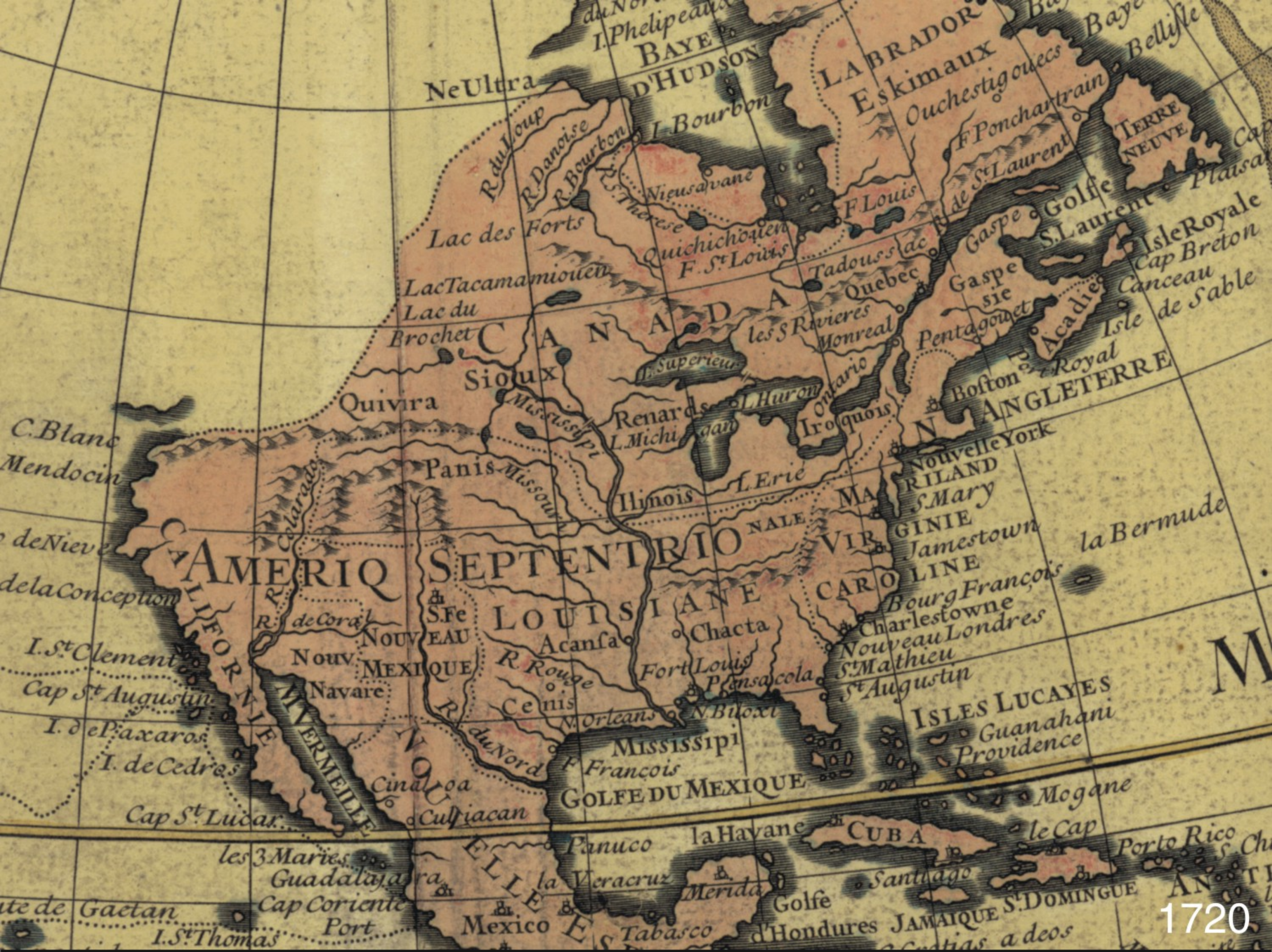
And then the tsunami-

Nature, to be commanded,
must be obeyed
Francis Bacon,
Novum Organum



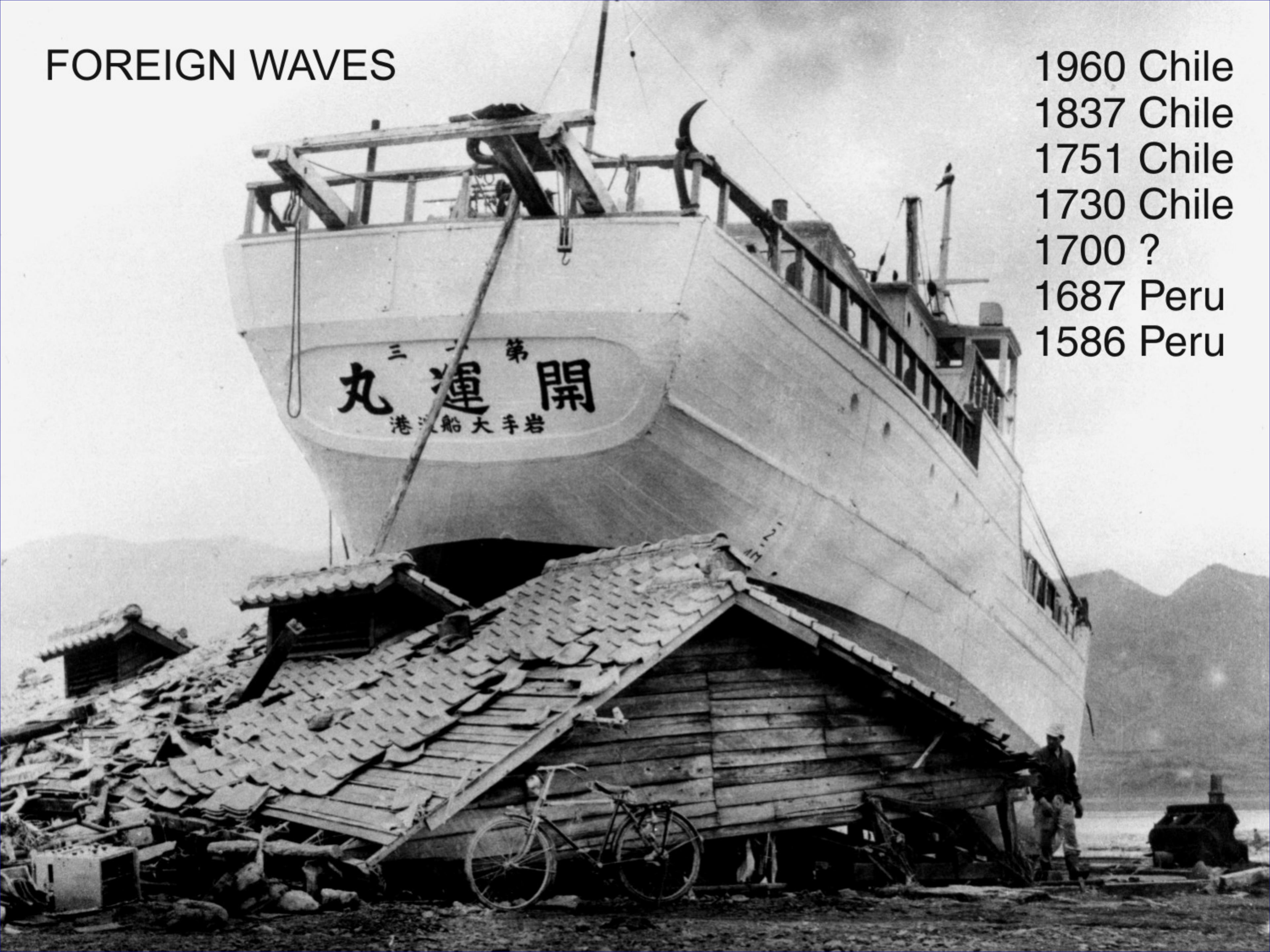
Giant earthquake, M 9

Series of lesser events, M 8+


I. Phelipeaux
BAYE D'HUDSON
LABRADOR
Eskimaux
Ouchestigouecs
Baye
Belliſle
Ne Ultra
I. Bourbon
R. du Loup
R. Danoise
R. Bourbon
R. S. Therese
Nieusavane
F. Ponchartrain
TERRE NEUVE
F. Louis
R. de St. Laurent
Golfe S. Laurent
Gaspe
Isle Royale
Cap Breton
Plaisance
Lac des Forts
Quichichouen
F. St. Louis
Tadoussac
Quebec
Gaspesie
Canceau
Acadie
Isle de Sable
Lac Tacamamiouen
Lac du Brochet
CANADA
les 3 Rivieres
Monreal
Pentagouet
Port Royal
L. Superieur
Sioux
Boston
N. ANGLETERRE
Quivira
Mississipi
Renards
L. Huron
Ontario
Iroquois
C. Blanc
Mendocin
L. Michigan
Nouvelle York
Panis
Missouri
L. Erie
MARILAND
S. Mary
R. Colarado
Ilinois
VIRGINIE
Jamestown
la Bermude
AMERIQ SEPTENTRIONALE
CAROLINE
Bourg François
de Nieve
de la Conception
CALIFORNIE
R. de Coral
S. Fe
LOUISIANE
Acansa
Chacta
Charlestowne
Nouveau Londres
I. St. Clement
Nouv. Navare
NOUVEAU MEXIQUE
R. Rouge
Fort Louis
Pensacola
St. Mathieu
St. Augustin
Cap St. Augustin
I. de Paxaros
I. de Cedres
MER VERMEILLE
Cenis
N. Orleans
N. Biloxi
R. du Nord
ISLES LUCAYES
Guanahani
Providence
Mississipi
F. François
GOLFE DU MEXIQUE
Cinaloa
Culiacan
Cap St. Lucar
NOUVELLE ESPAGNE
Mogane
Panuco
la Havane
CUBA
le Cap
Porto Rico
les 3 Maries
Guadalajara
la Veracruz
Merida
Santiago
Golfe d'Hondures
JAMAIQUE
S. DOMINGUE
ANTILLES
Gaetan
Cap Coriente
Port
Mexico
Tabasco
I. St. Thomas
Gracias a deos

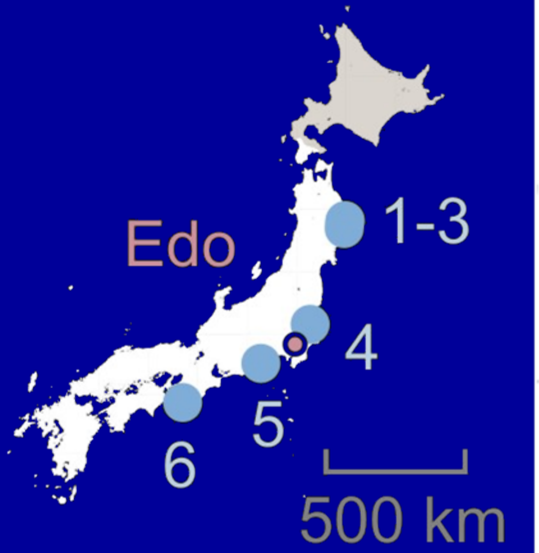
1720

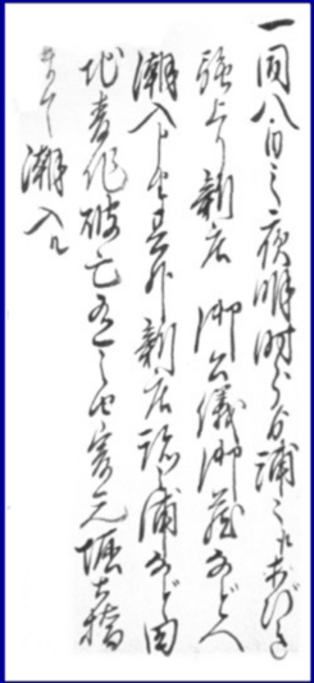
FOREIGN WAVES



1960 Chile
1837 Chile
1751 Chile
1730 Chile
1700 ?
1687 Peru
1586 Peru

1700 ORPHAN

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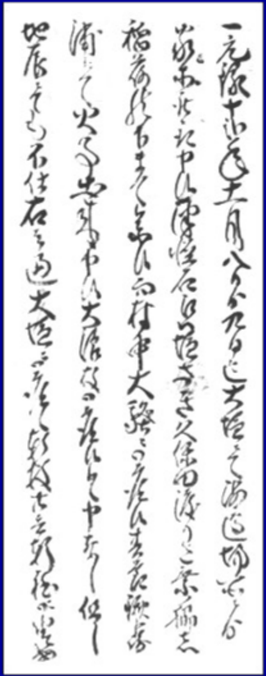
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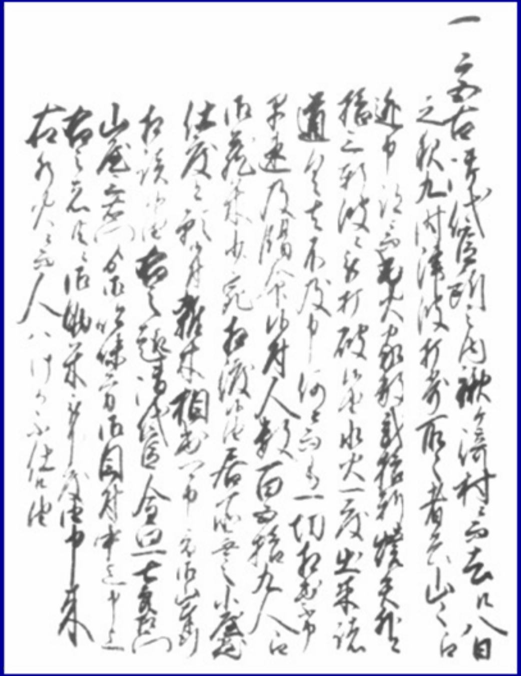
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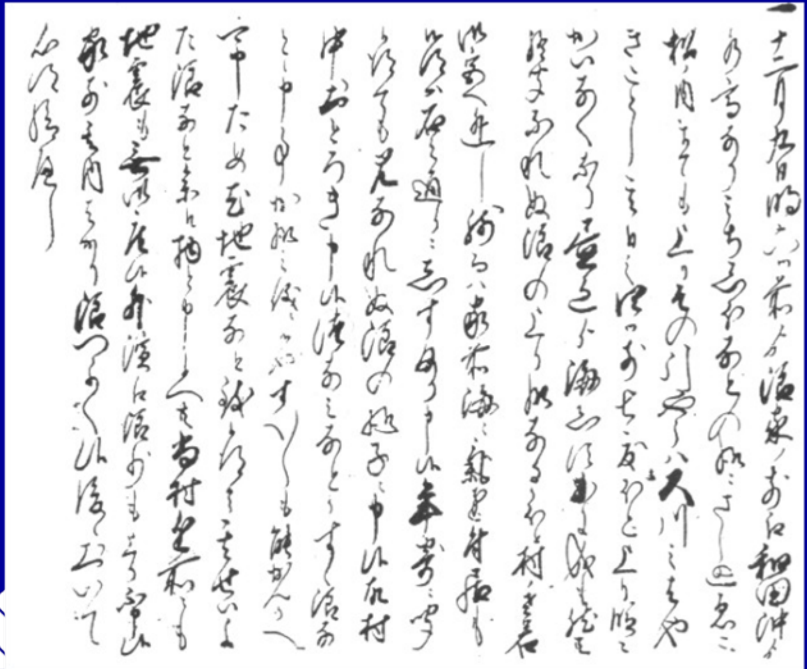
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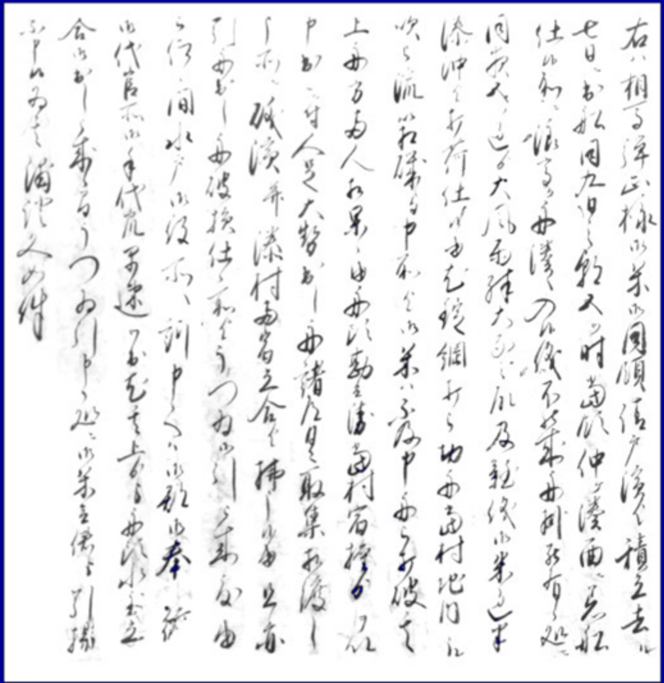
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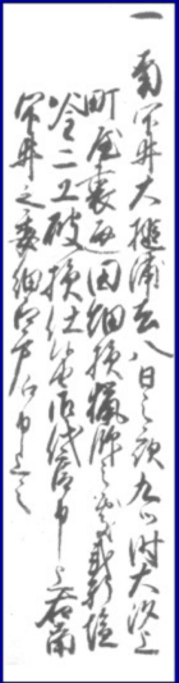
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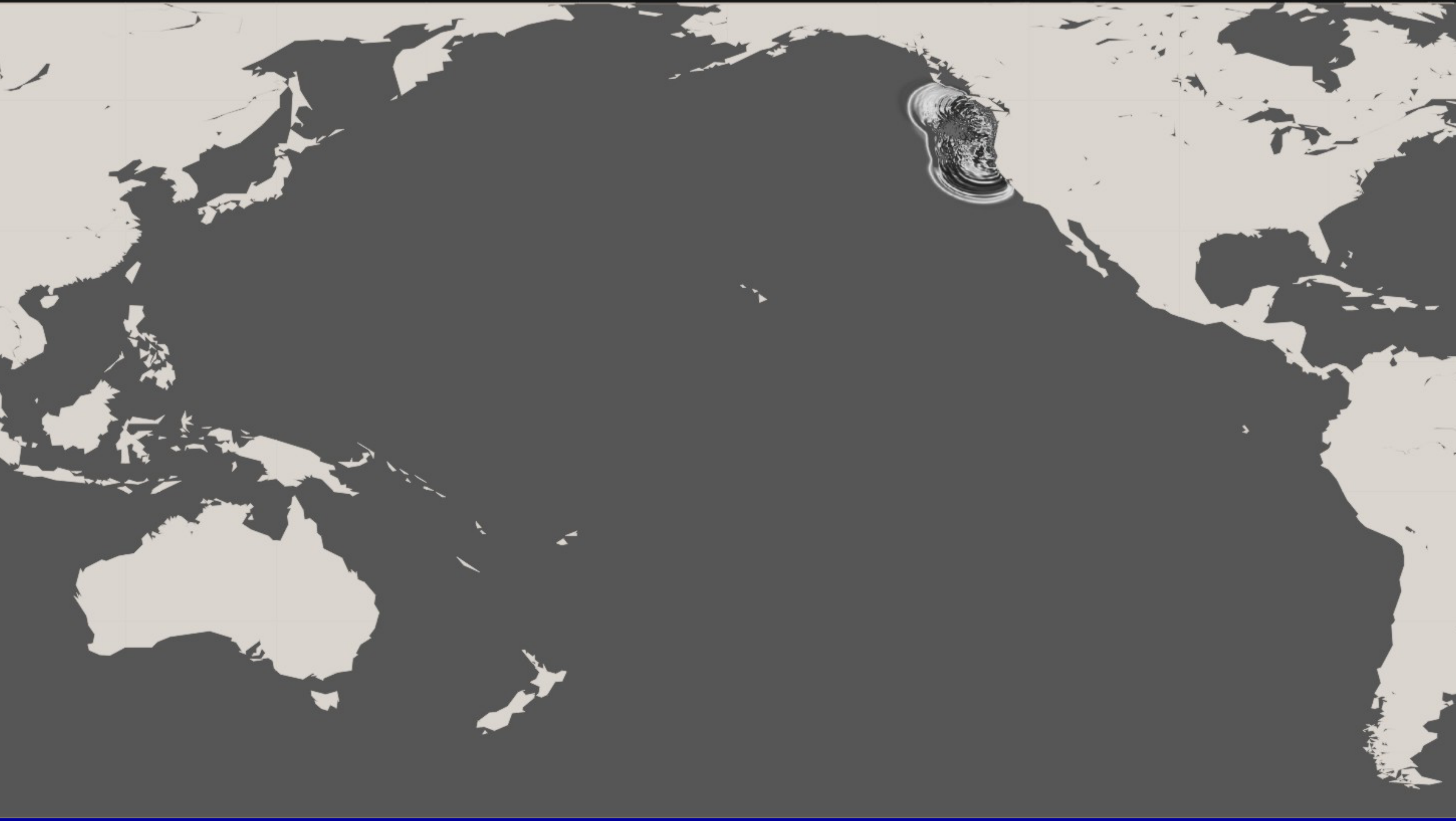
1 hour after earthquake



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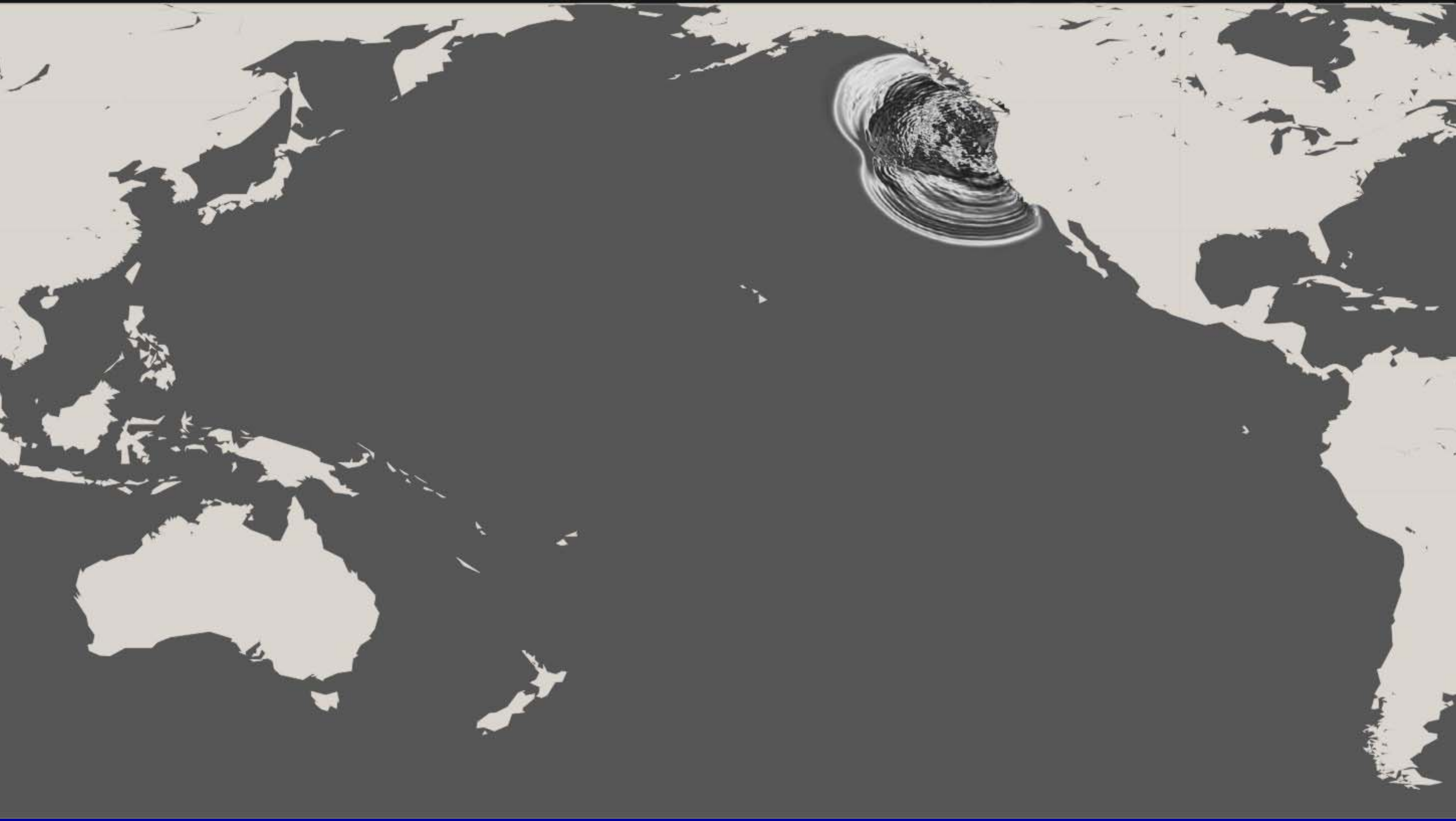
Model by Kenji Satake

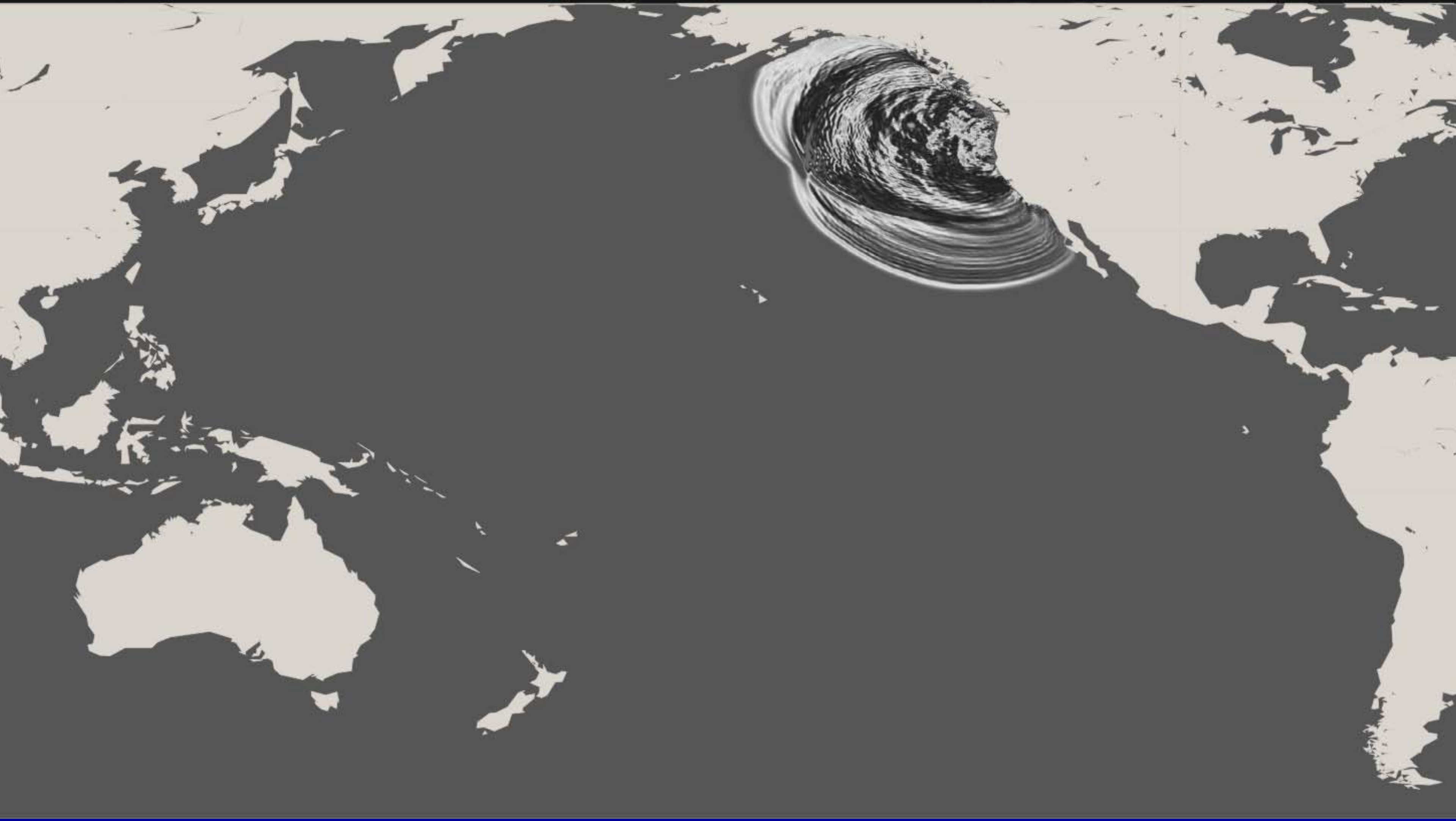
2 hours



WASHINGTON STATE DEPARTMENT OF **Natural Resources**

Model by Kenji Satake

3 hours



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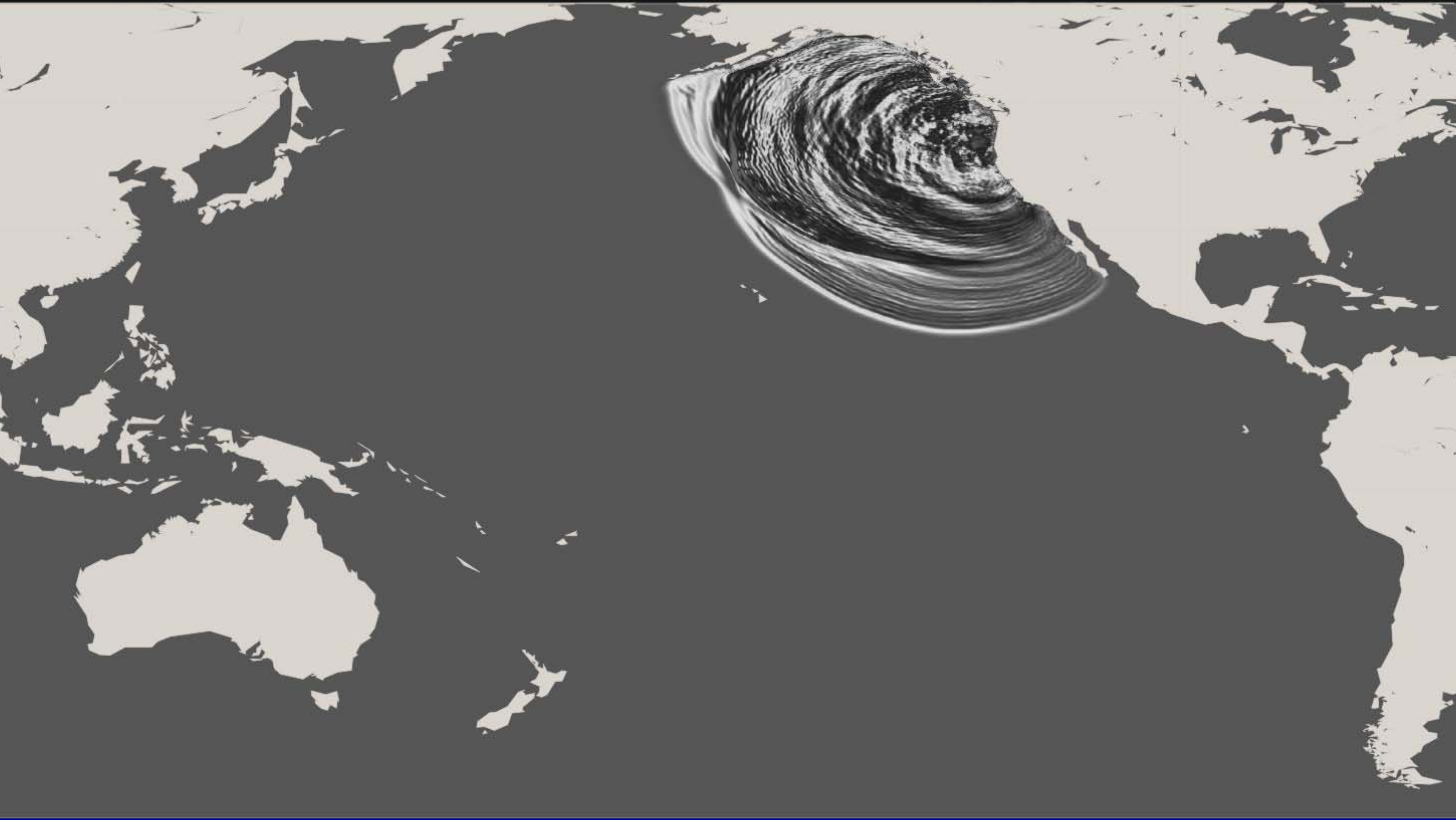
4 hours



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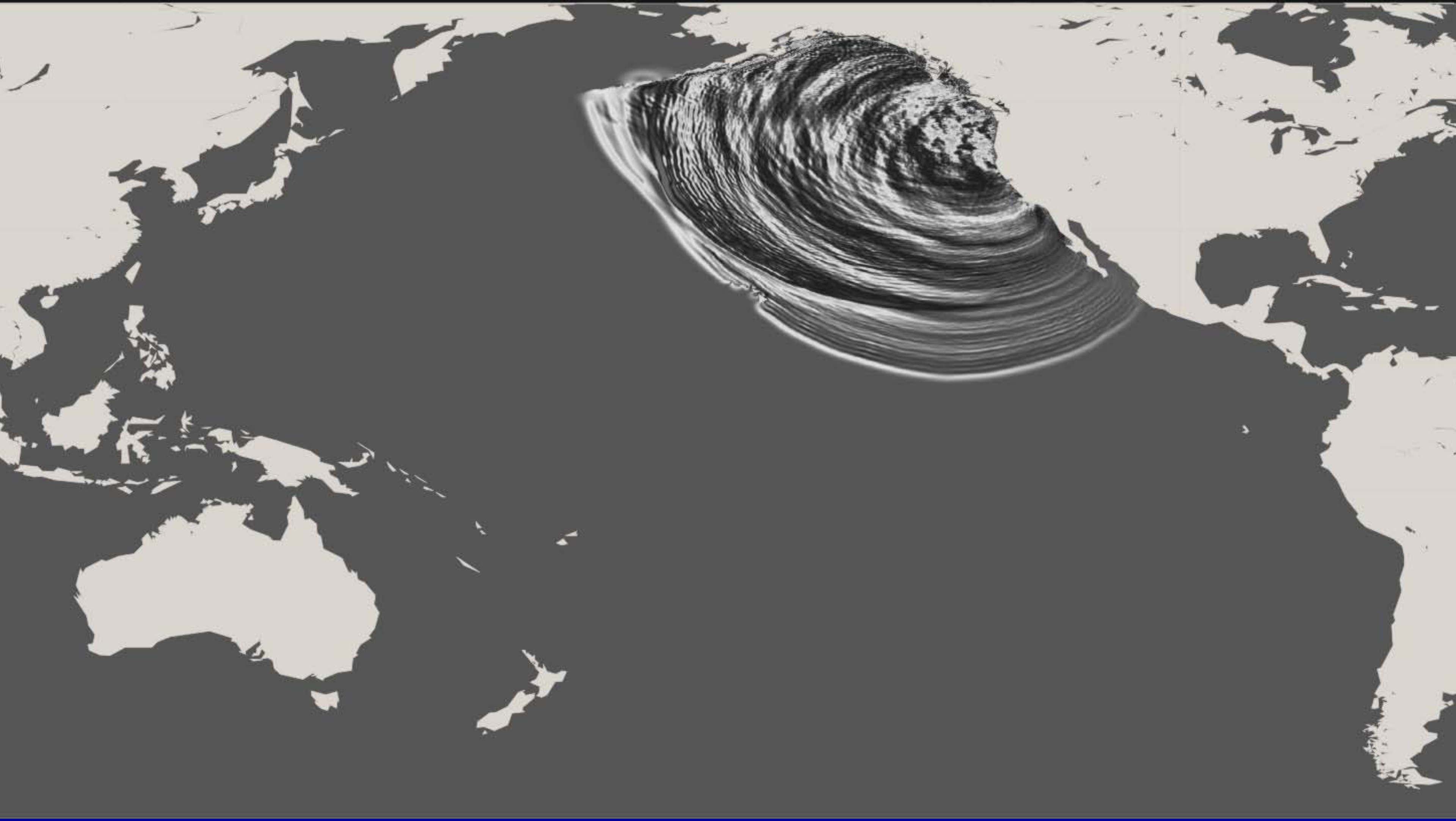
Model by Kenji Satake

5 hours



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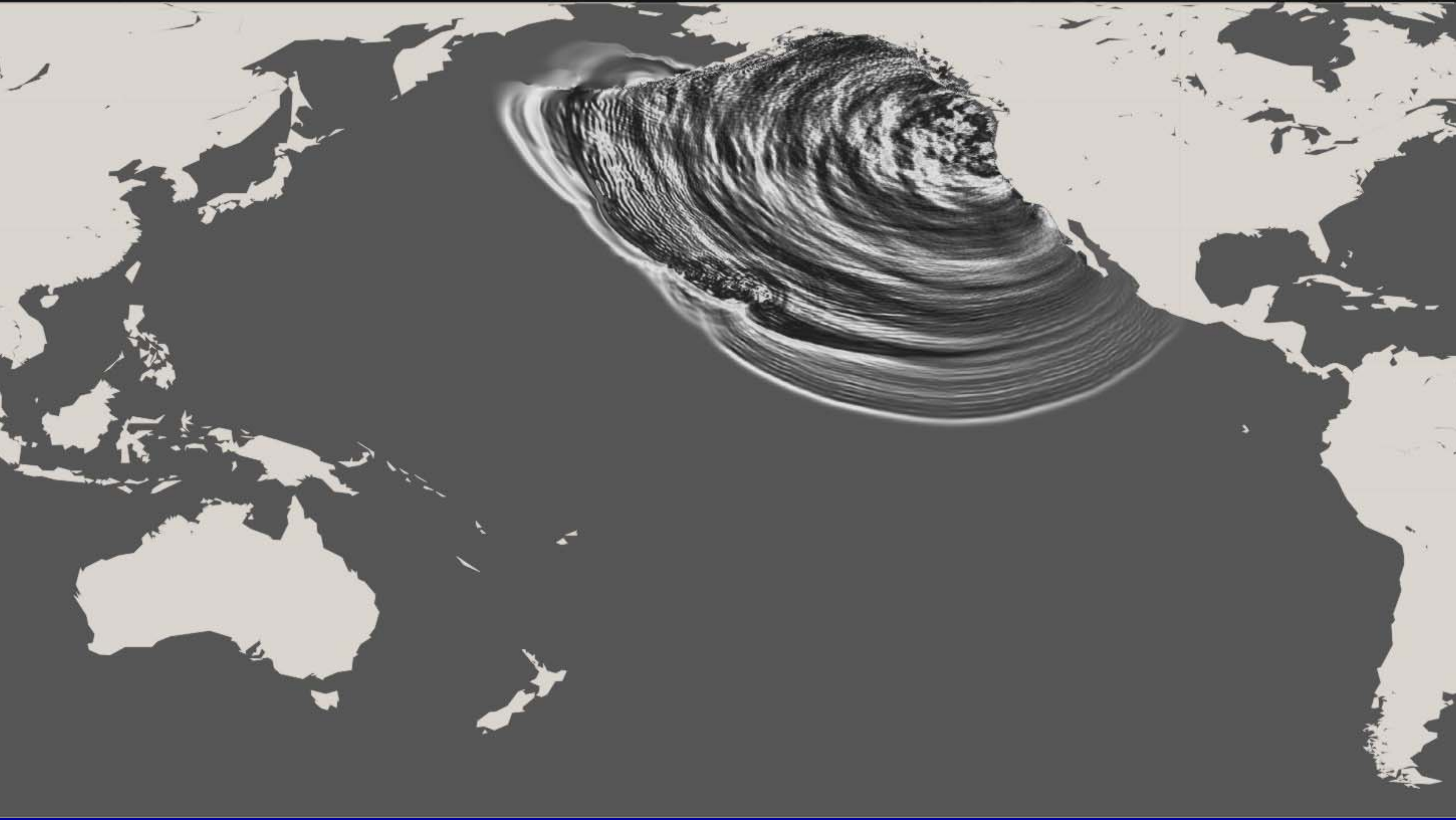
Model by Kenji Satake

6 hours



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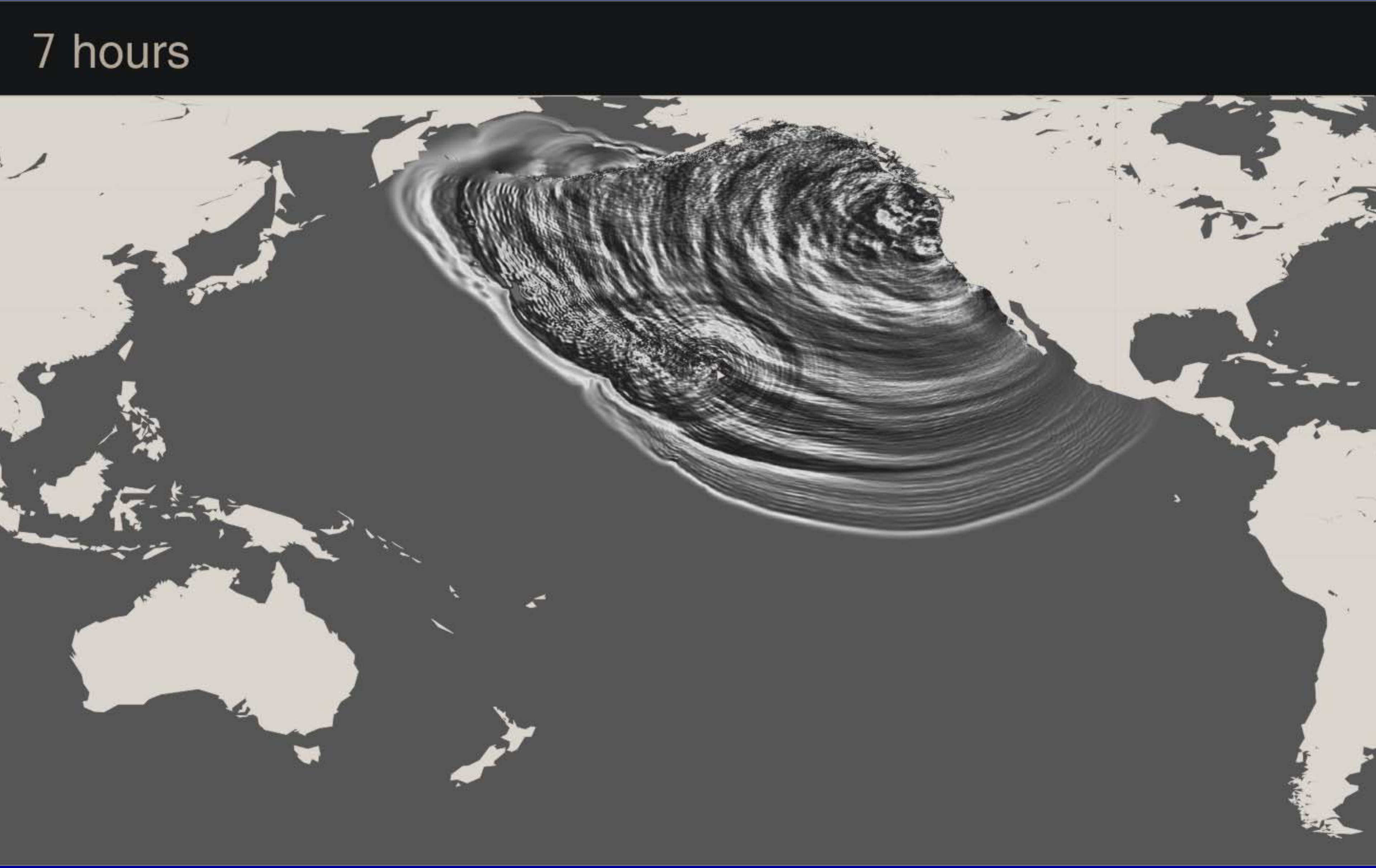
Model by Kenji Satake



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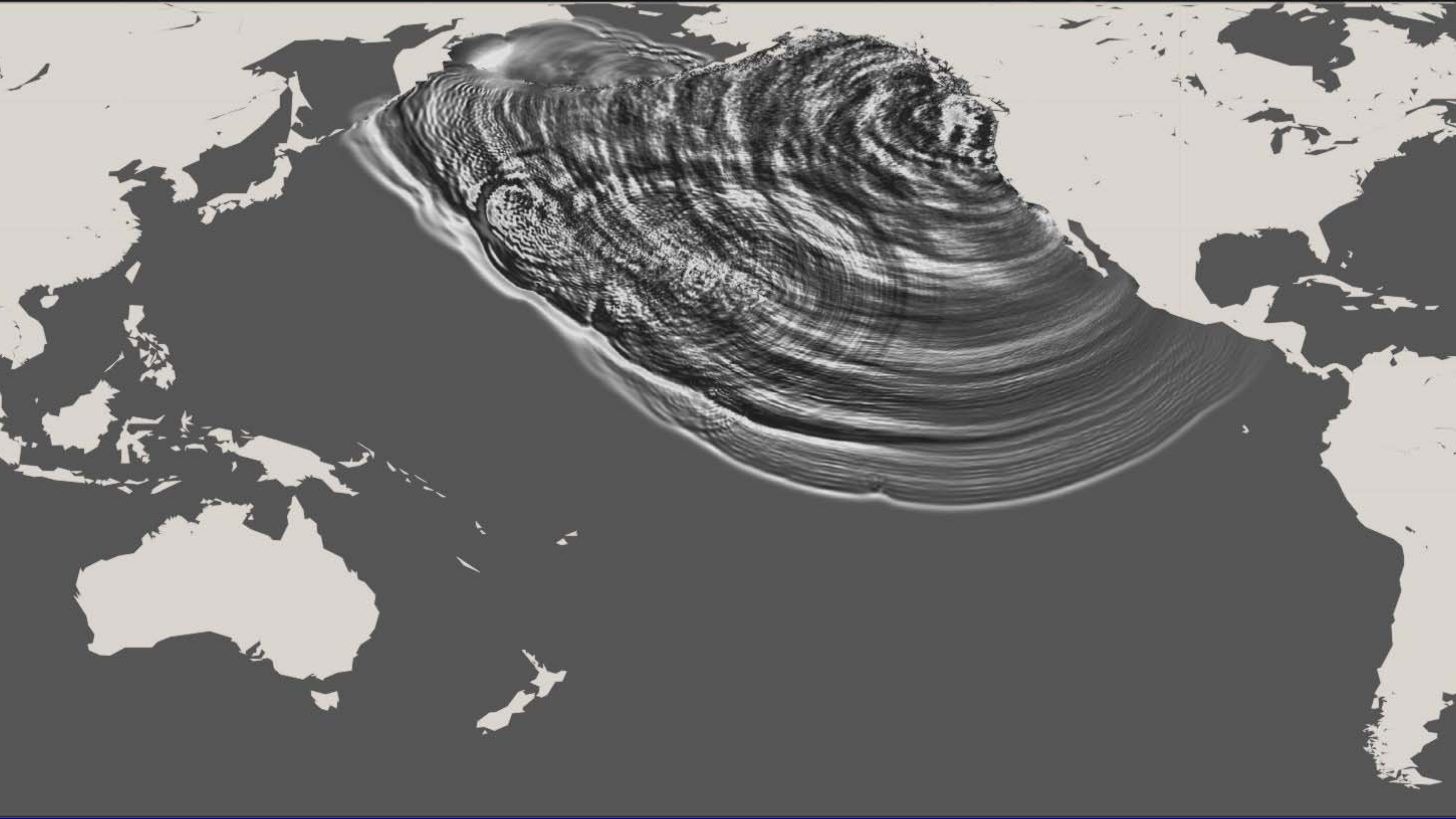
Model by Kenji Satake

8 hours



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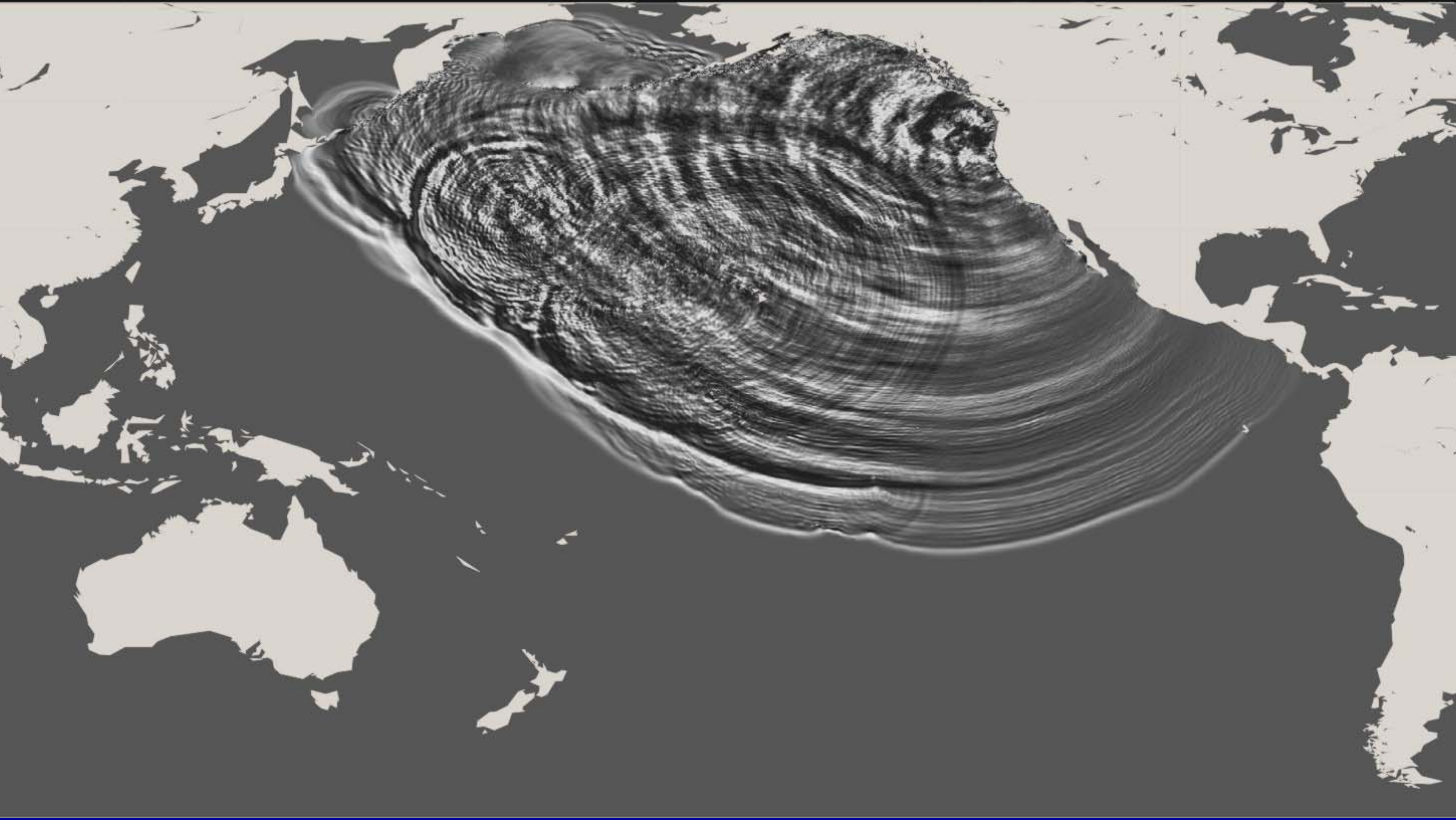
Model by Kenji Satake

9 hours



WASHINGTON STATE DEPARTMENT OF
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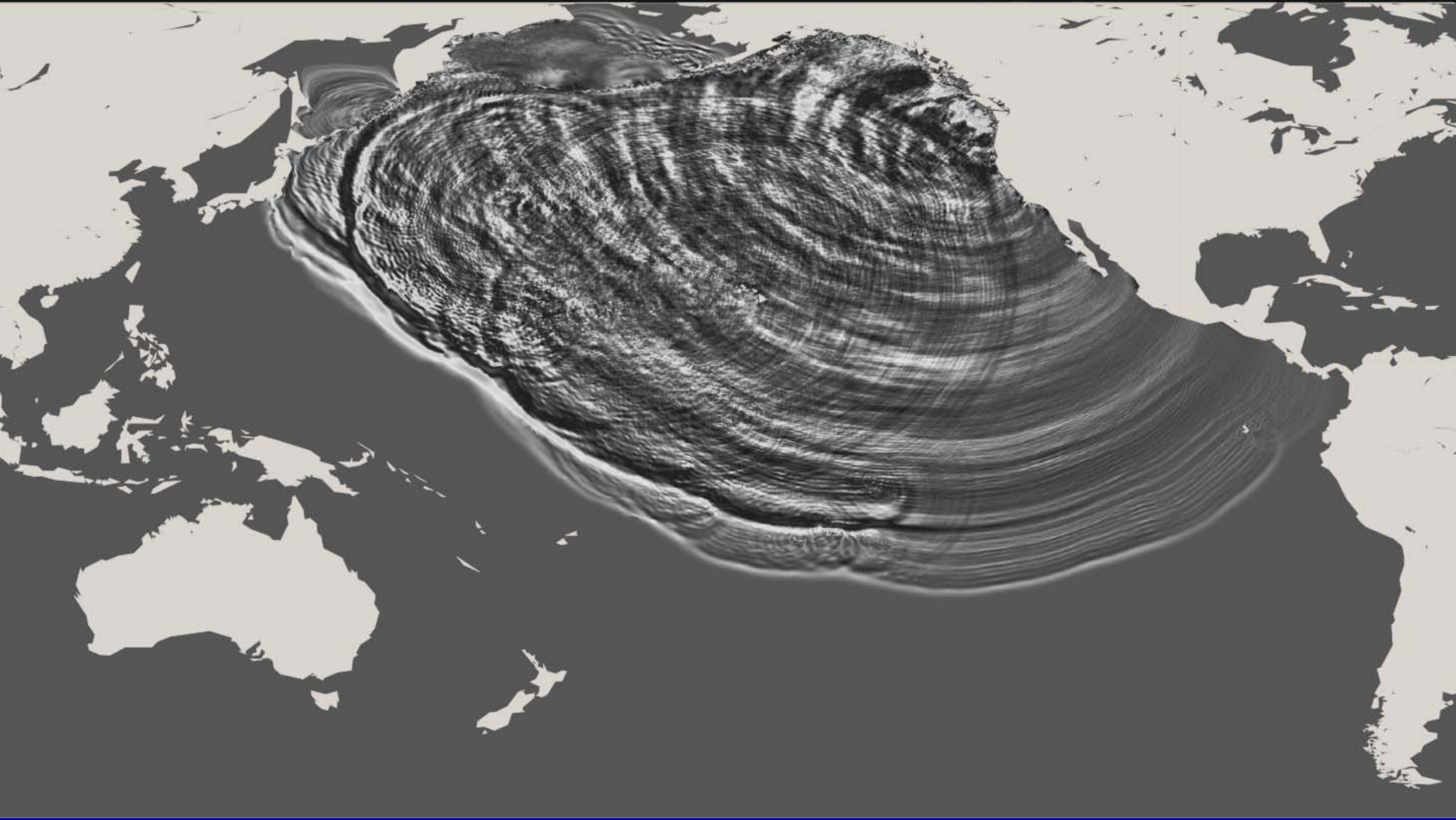
Model by Kenji Satake

10 hours



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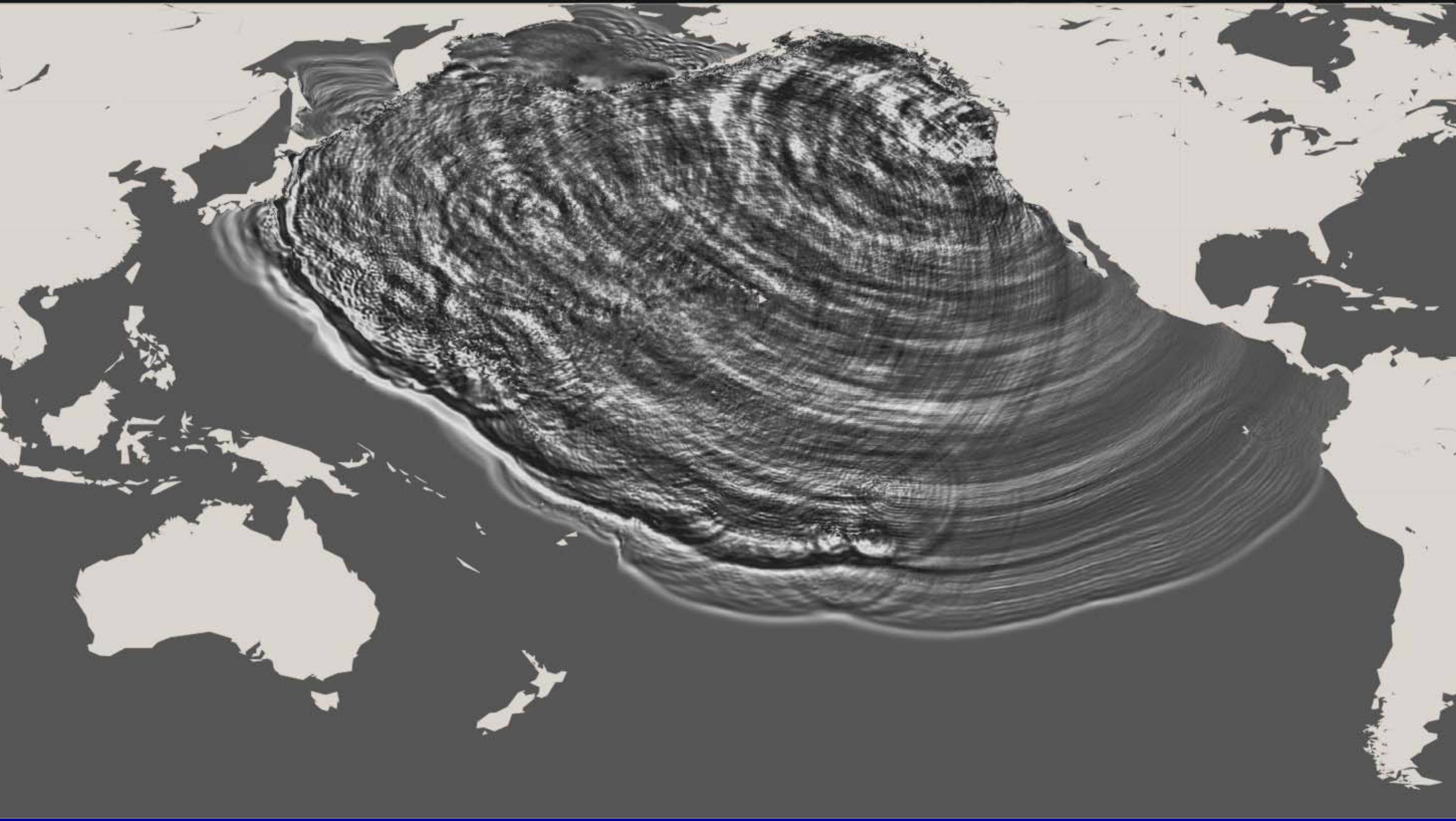
Model by Kenji Satake

11 hours



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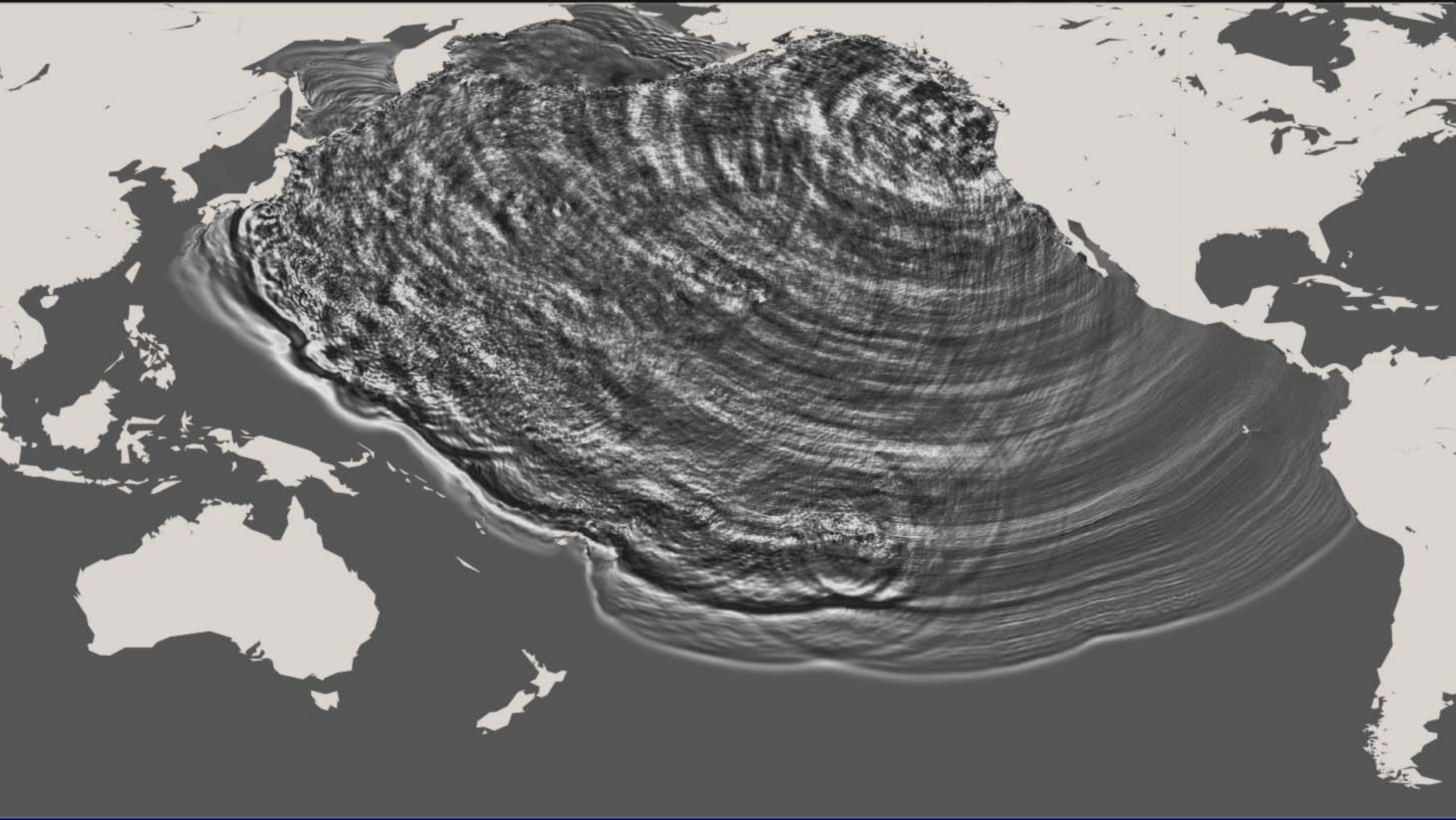
Model by Kenji Satake

12 hours



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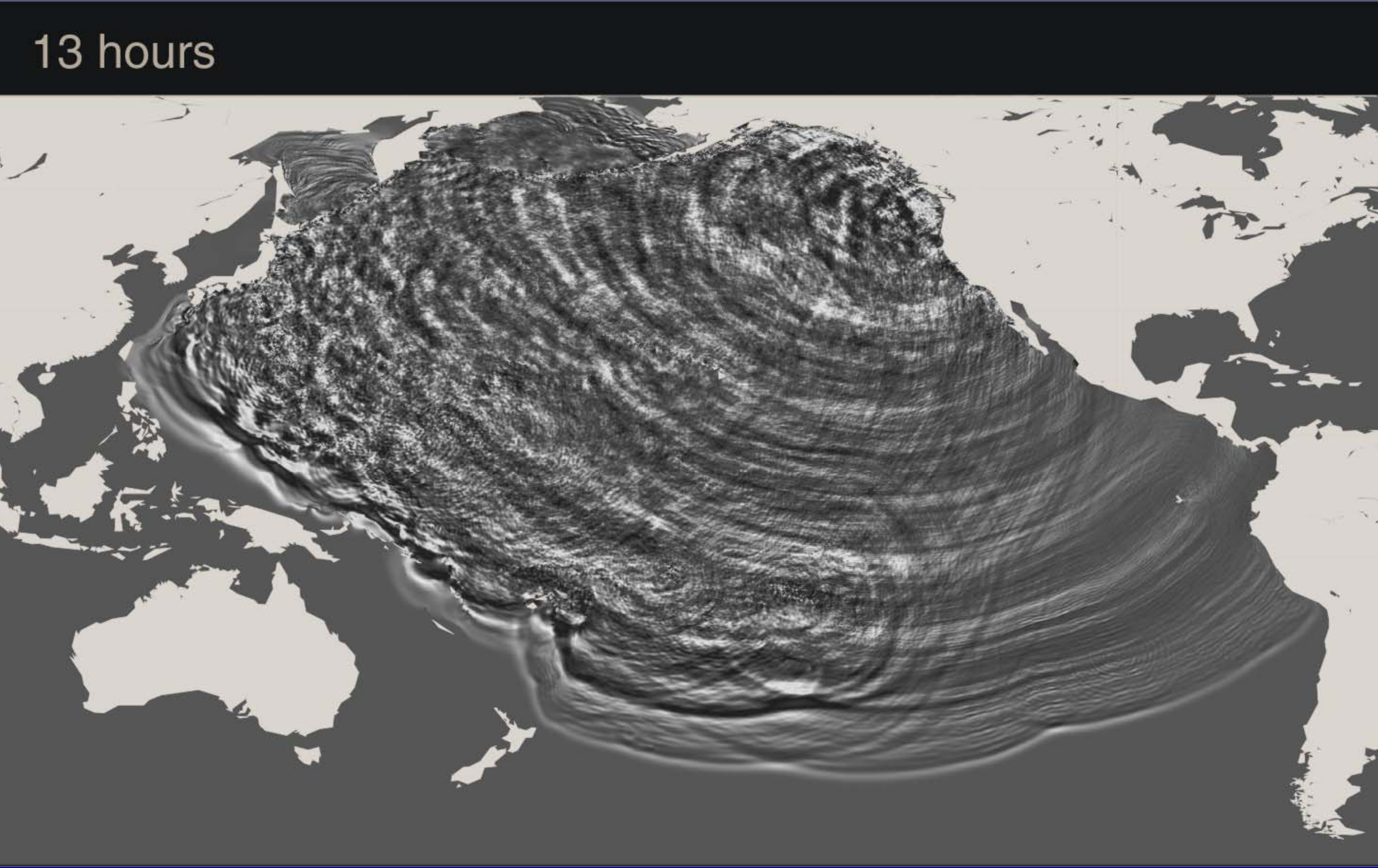
Model by Kenji Satake



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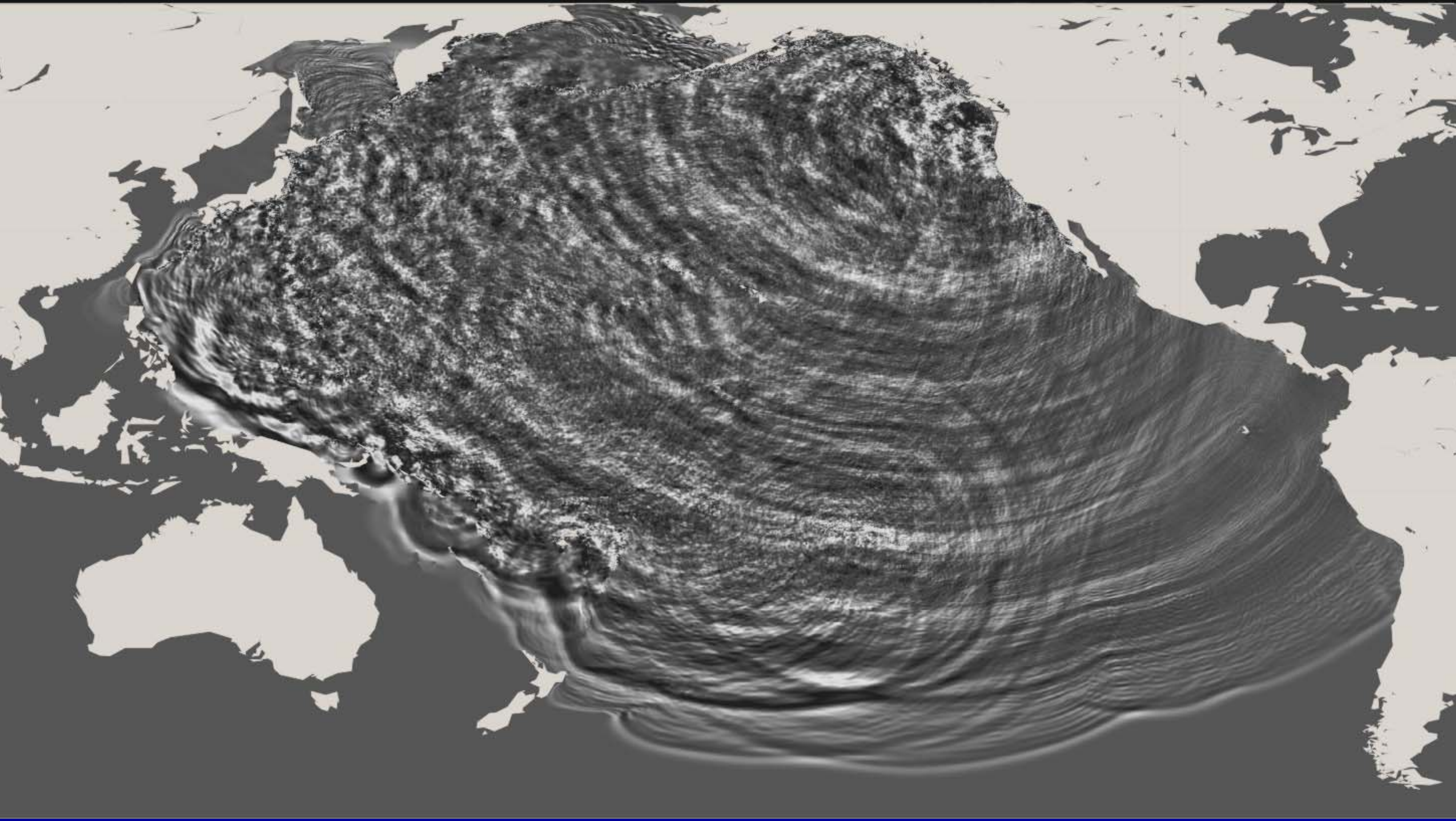
Model by Kenji Satake

14 hours



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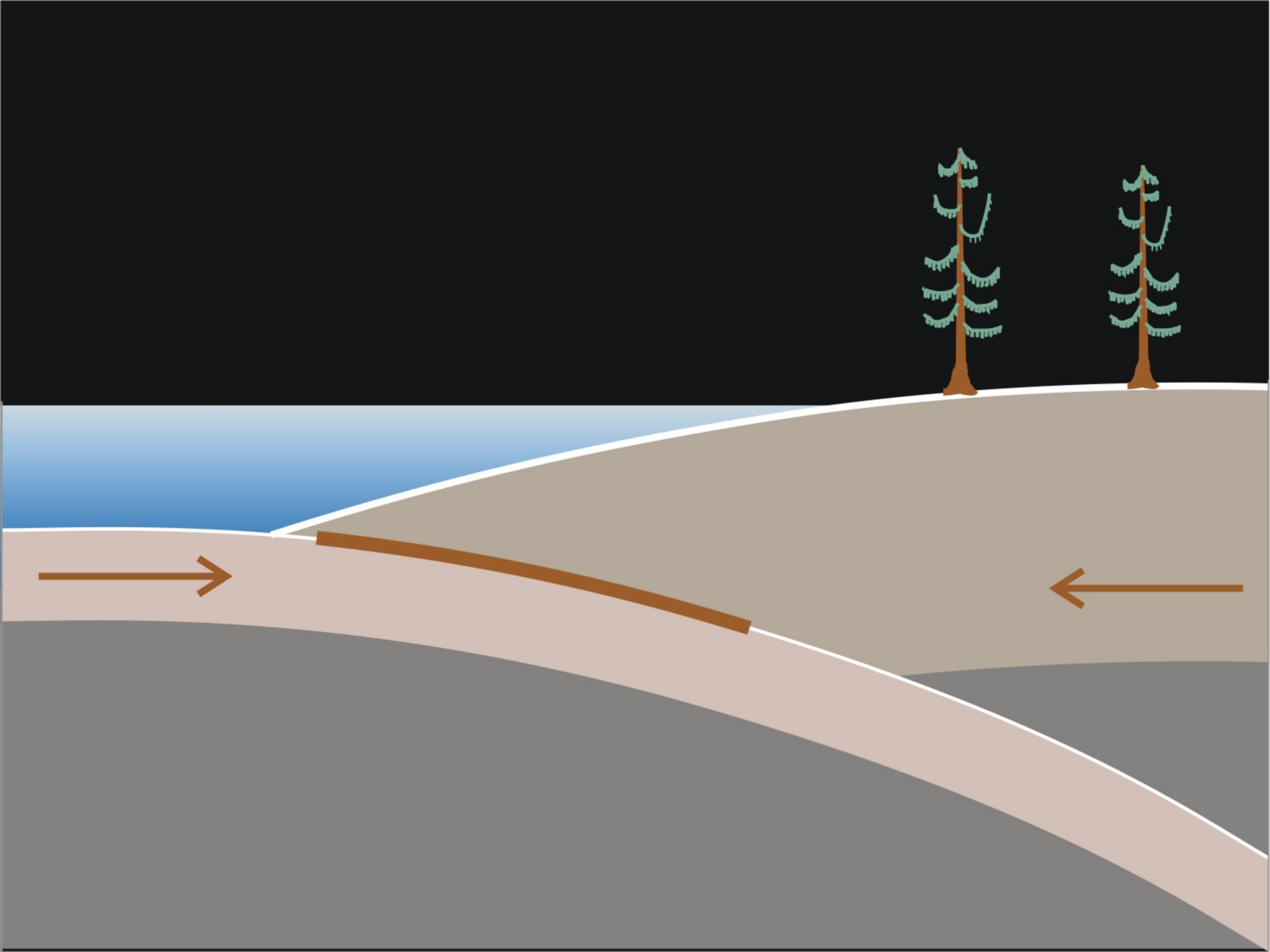
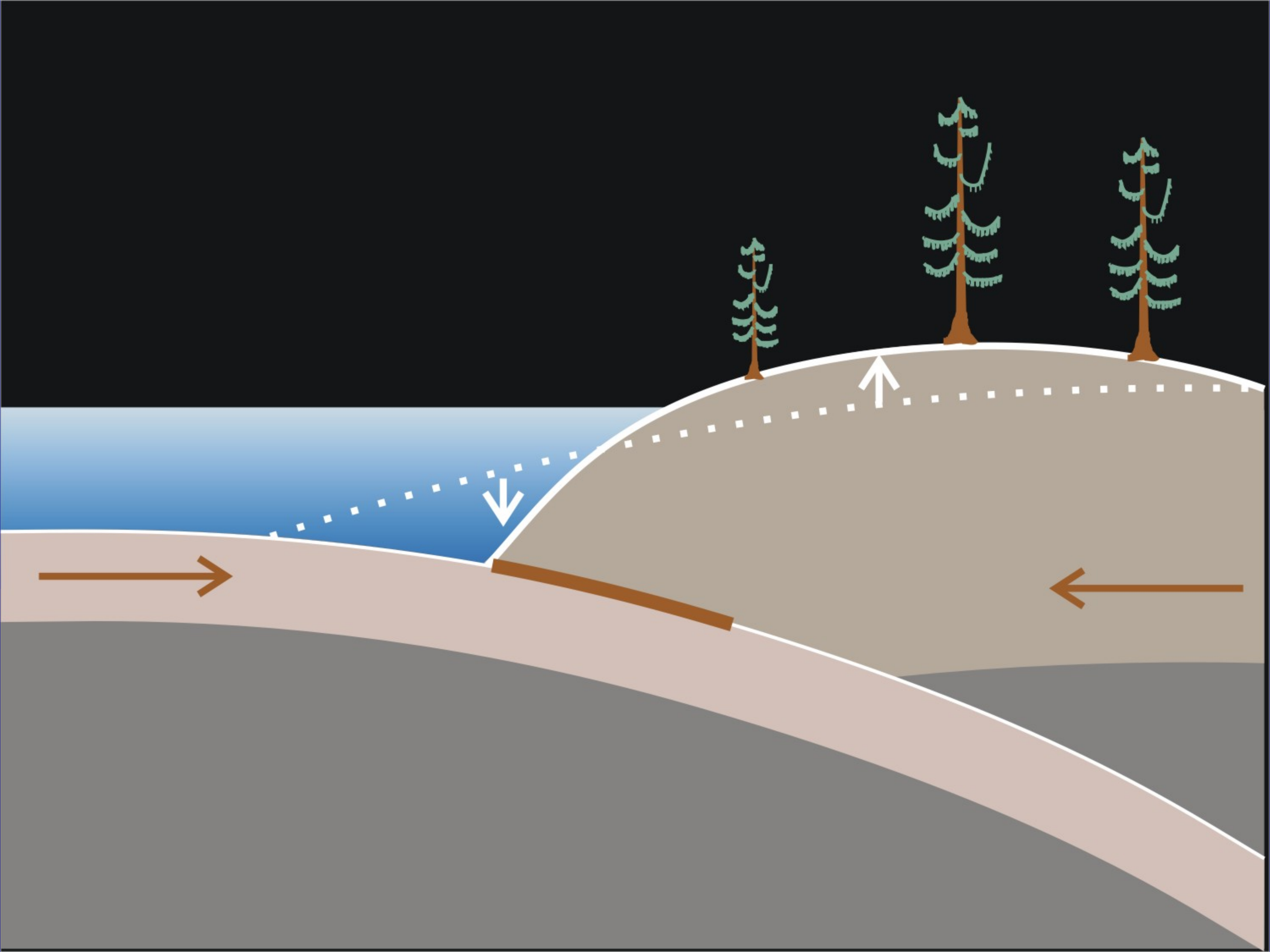
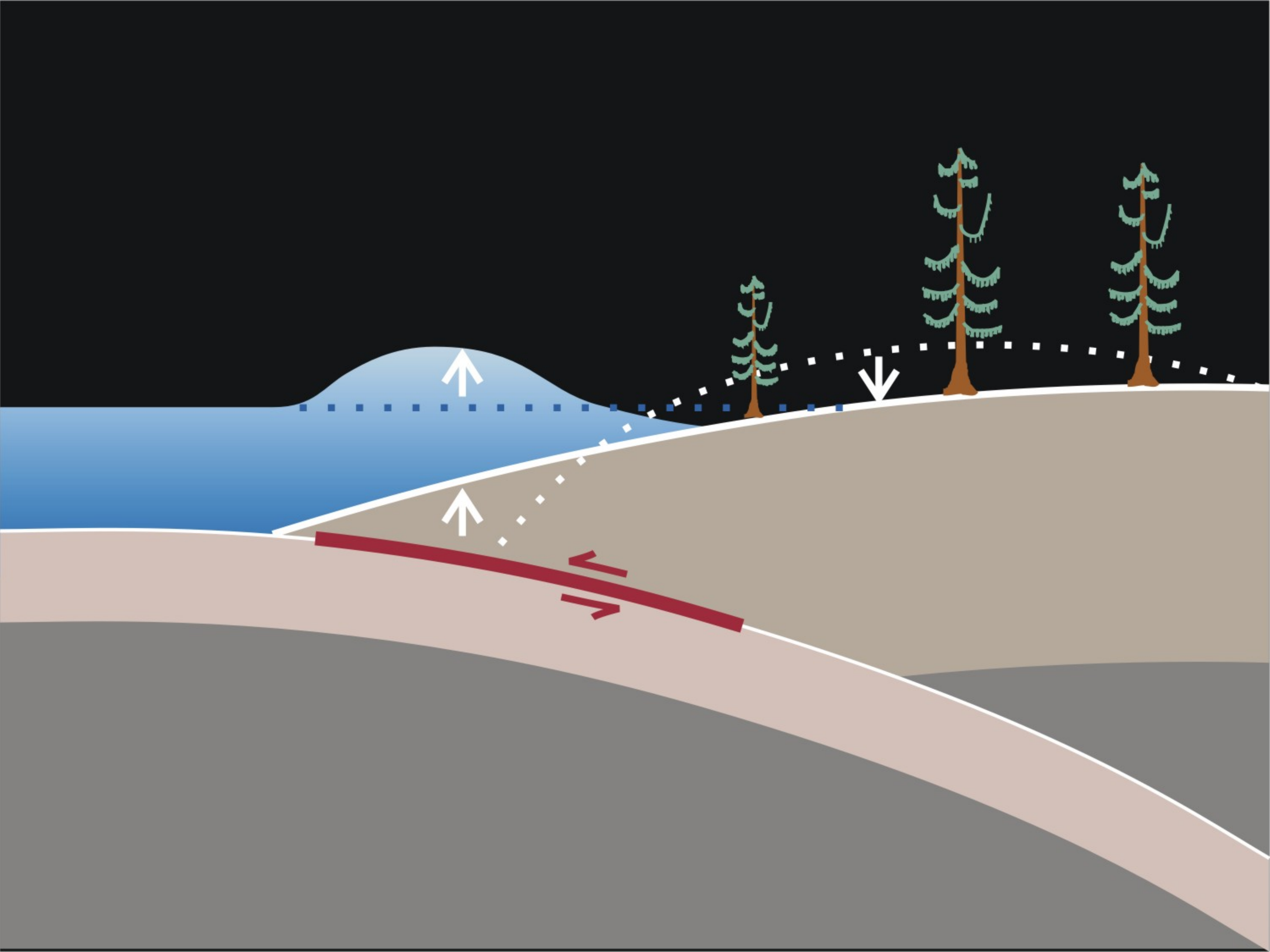
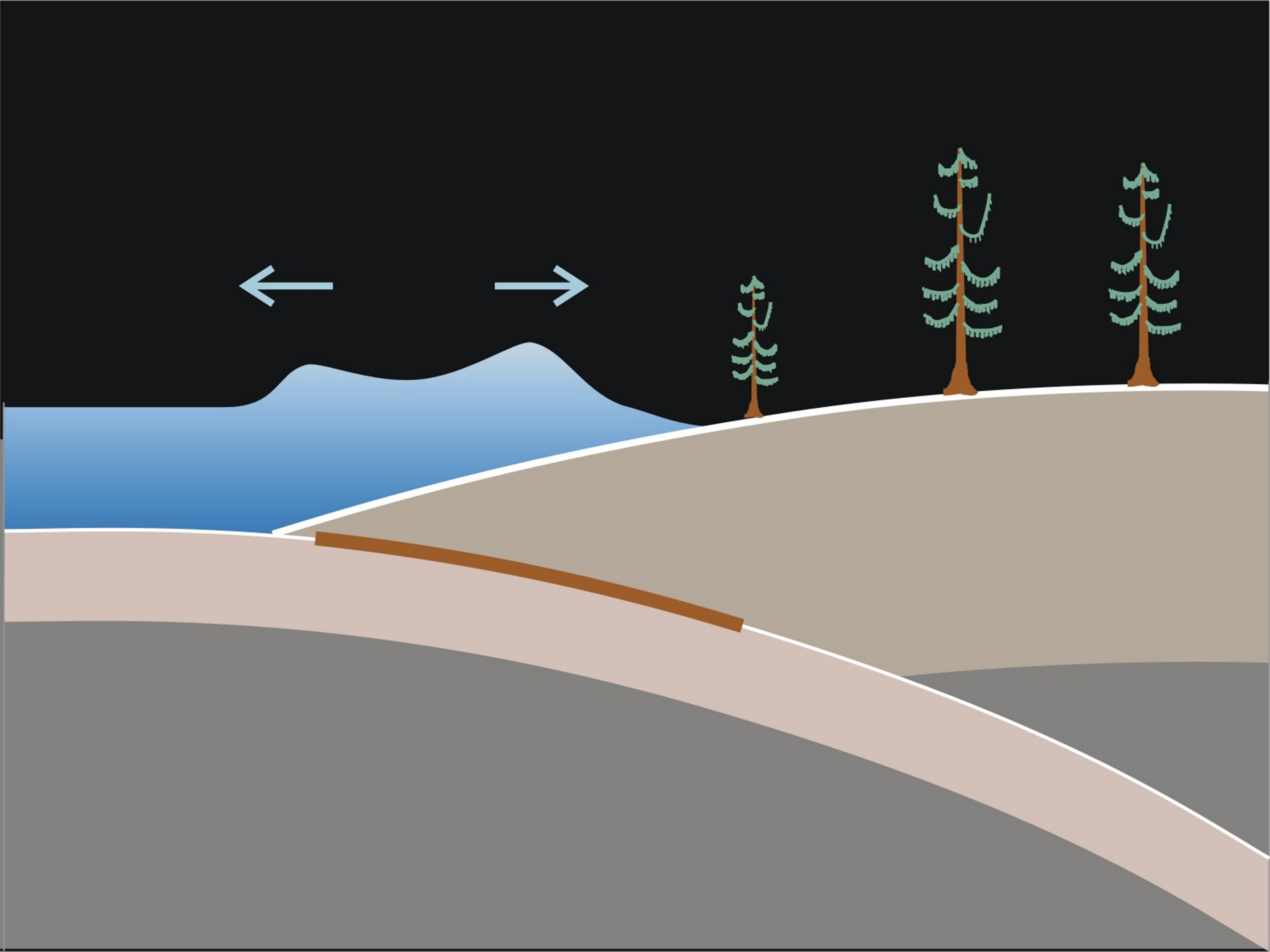
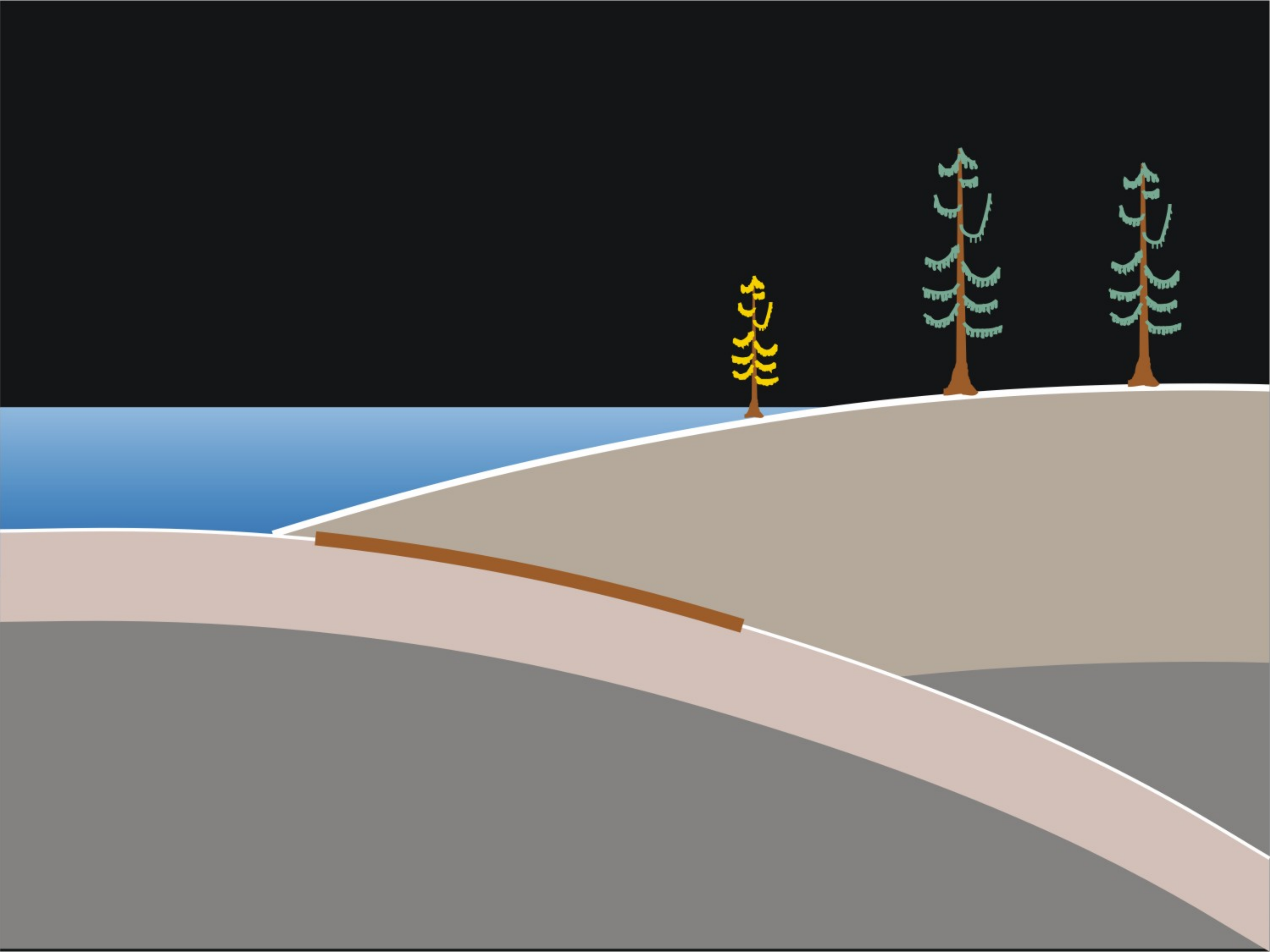
Model by Kenji Satake

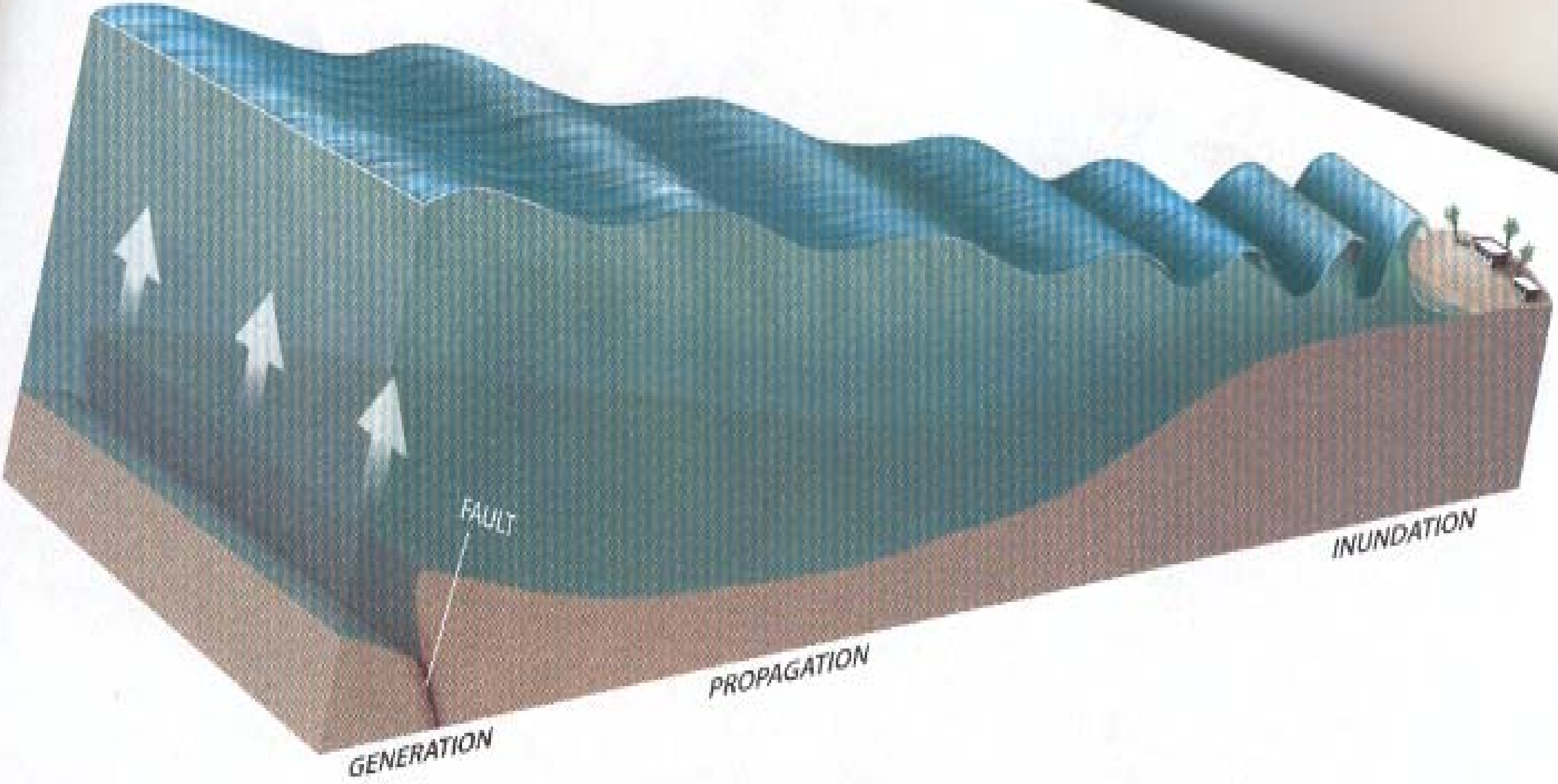






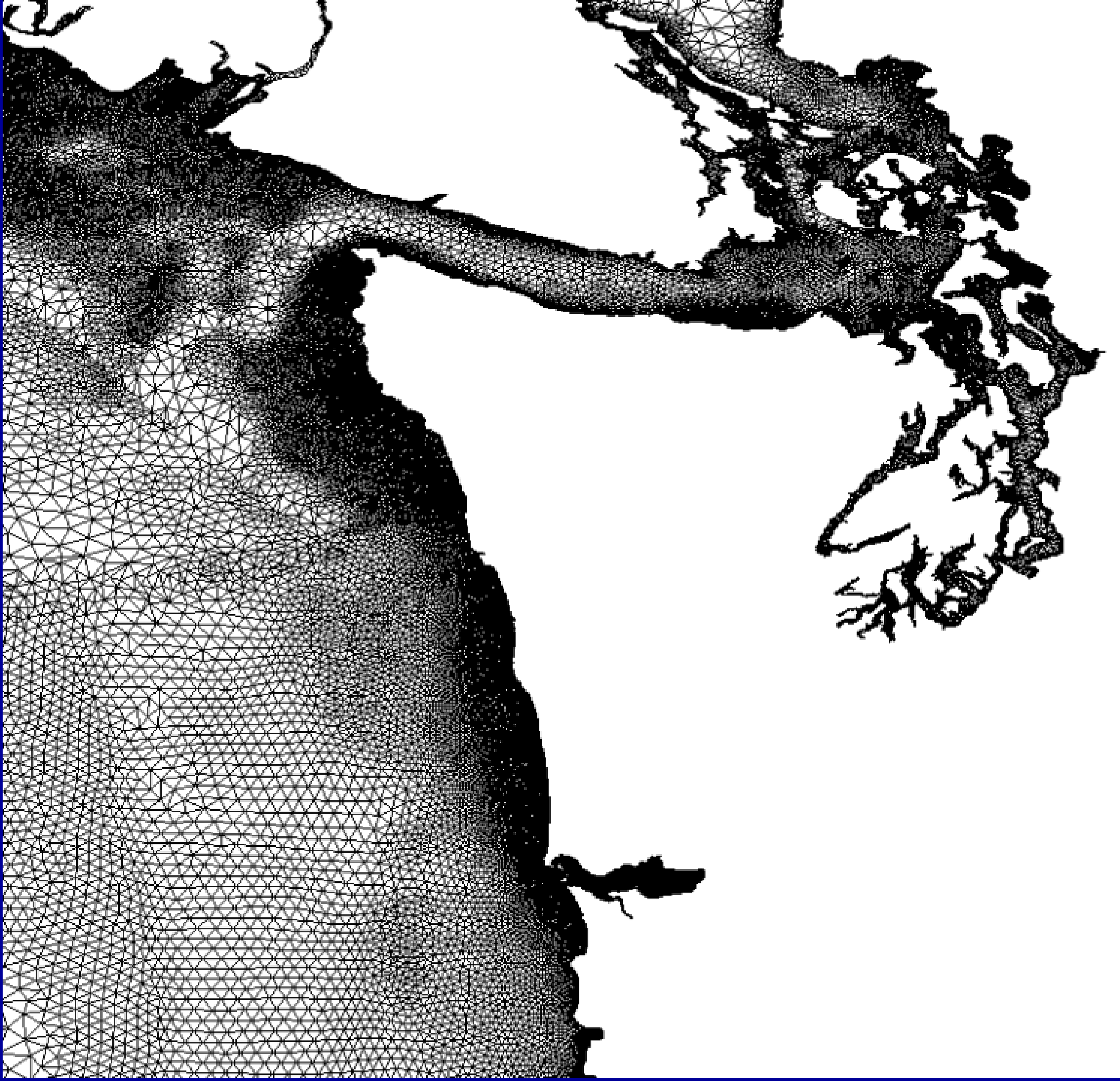


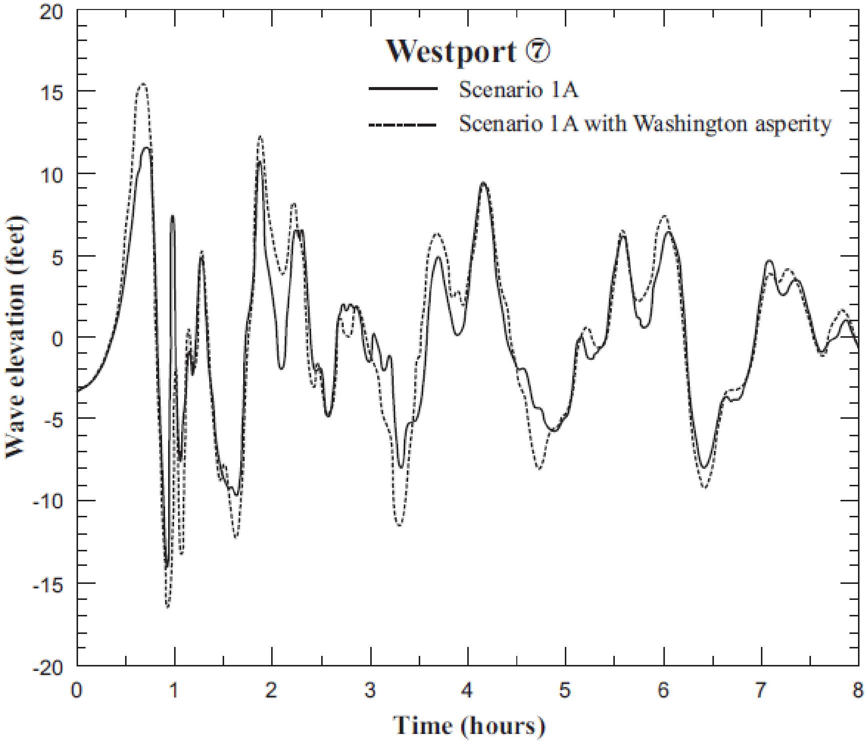




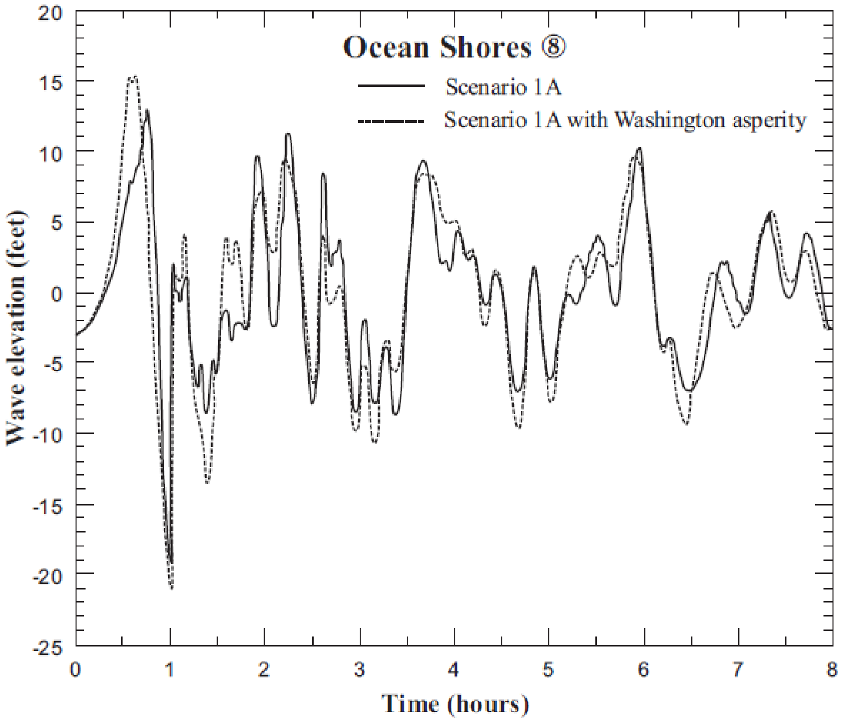
The realization that Cascadia was active was instrumental to the creation of the National Tsunami Hazard Mitigation Program, which develops tsunami inundation maps for vulnerable coastlines. These are based on a combination of numerical modeling, and , where possible, paleoseismology.

The model calculates the water surface elevation and velocity at each grid point



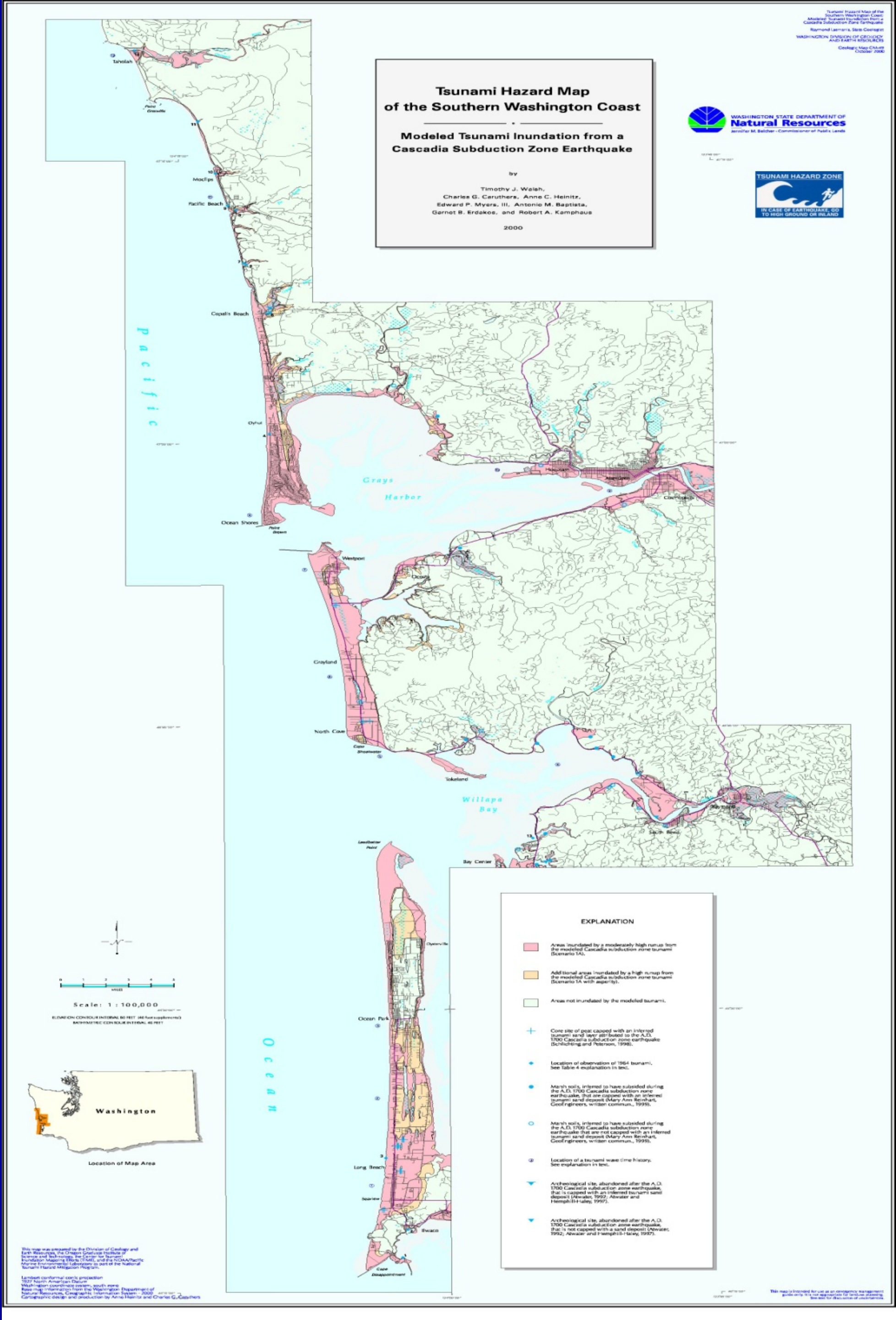


A tsunami generated by a Cascadia subduction zone earthquake will arrive in less than 45 minutes. For these events, as was the case in Banda Aceh, the earthquake must be the warning. Citizens must know where to evacuate from and where to evacuate to, and must do so quickly and on foot.

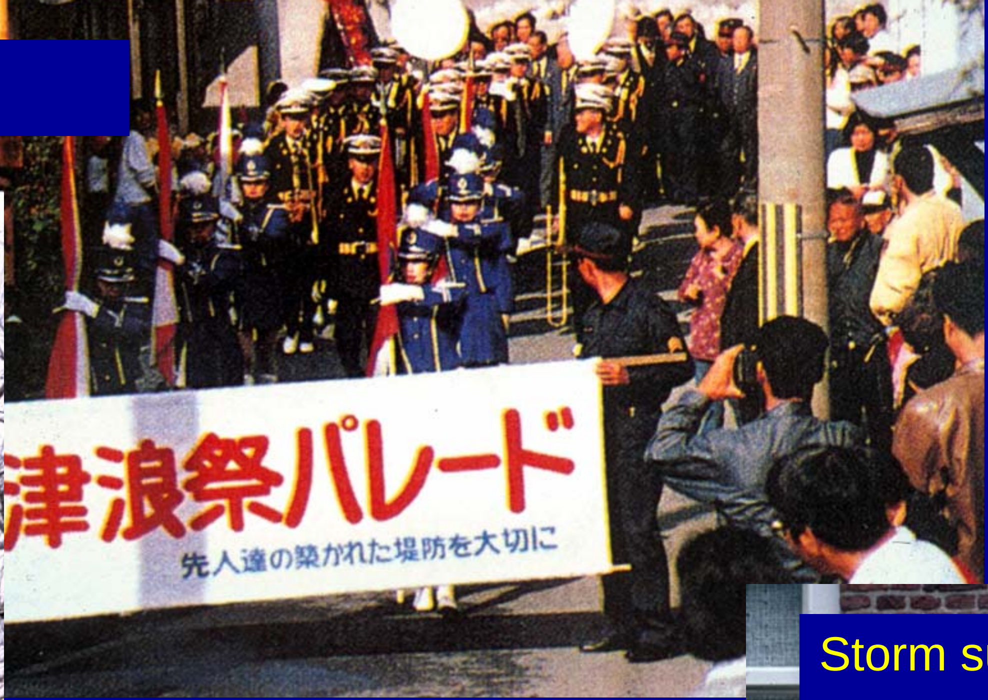


WASHINGTON STATE DEPARTMENT OF
Natural Resources

Note the long peninsulas or spits of low-lying ground. Ocean Shores peninsula is 7 miles long and Long Beach peninsula is 20 miles long with little or no high ground over those distances. For these areas, tsunami defenses are appropriate.


Tsunami Hazard Map of the Southern Washington Coast
Modeled Tsunami Inundation from a Cascadia Subduction Zone Earthquake
by
Timothy J. Walsh, Charles G. Caruthers, Anne C. Heinitz, Edward P. Myers, III, Antonio M. Baptista, Garnet B. Erdakos, and Robert A. Kamphaus
2000
WASHINGTON STATE DEPARTMENT OF Natural Resources
TSUNAMI HAZARD ZONE
IN CASE OF EARTHQUAKE, GO TO HIGH GROUND OR INLAND
Taholah
Point Grenville
Moclips
Pacific Beach
Copalis Beach
Pacific
Ocean City
Ocean Shores
Point Brown
Grays Harbor
Hoquiam
Aberdeen
Cosmopolis
Westport
Grayland
North Cove
Cape Shoalwater
Tokeland
Willapa Bay
Raymond
South Bend
Bay Center
Leadbetter Point
Oysterville
Ocean Park
Ocean
Long Beach
Seaview
Ilwaco
Cape Disappointment
Scale 1:100,000
Washington
Location of Map Area
EXPLANATION
Areas inundated by a moderately high runup from the modeled Cascadia subduction zone tsunami (Scenario 1A).
Additional areas inundated by a high runup from the modeled Cascadia subduction zone tsunami (Scenario 1A with asperity).
Areas not inundated by the modeled tsunami.
Core site of peat capped with an inferred tsunami sand layer attributed to the A.D. 1700 Cascadia subduction zone earthquake (Schlichting and Peterson, 1998).
Location of observation of 1964 tsunami. See Table 4 explanation in text.
Marsh soils, inferred to have subsided during the A.D. 1700 Cascadia subduction zone earthquake, that are capped with an inferred tsunami sand deposit (Mary Ann Reinhart, GeoEngineers, written commun., 1999).
Marsh soils, inferred to have subsided during the A.D. 1700 Cascadia subduction zone earthquake that are not capped with an inferred tsunami sand deposit (Mary Ann Reinhart, GeoEngineers, written commun., 1999).
Location of a tsunami wave time history. See explanation in text.
Archeological site, abandoned after the A.D. 1700 Cascadia subduction zone earthquake, that is capped with an inferred tsunami sand deposit (Atwater, 1992; Atwater and Hemphill-Haley, 1997).
Archeological site, abandoned after the A.D. 1700 Cascadia subduction zone earthquake, that is not capped with a sand deposit (Atwater, 1992; Atwater and Hemphill-Haley, 1997).

Tsunami parade at Hiro.


津浪祭パレード
先人達の築かれた堤防を大切に

Tsunami monument

REMEMBER THE PAST

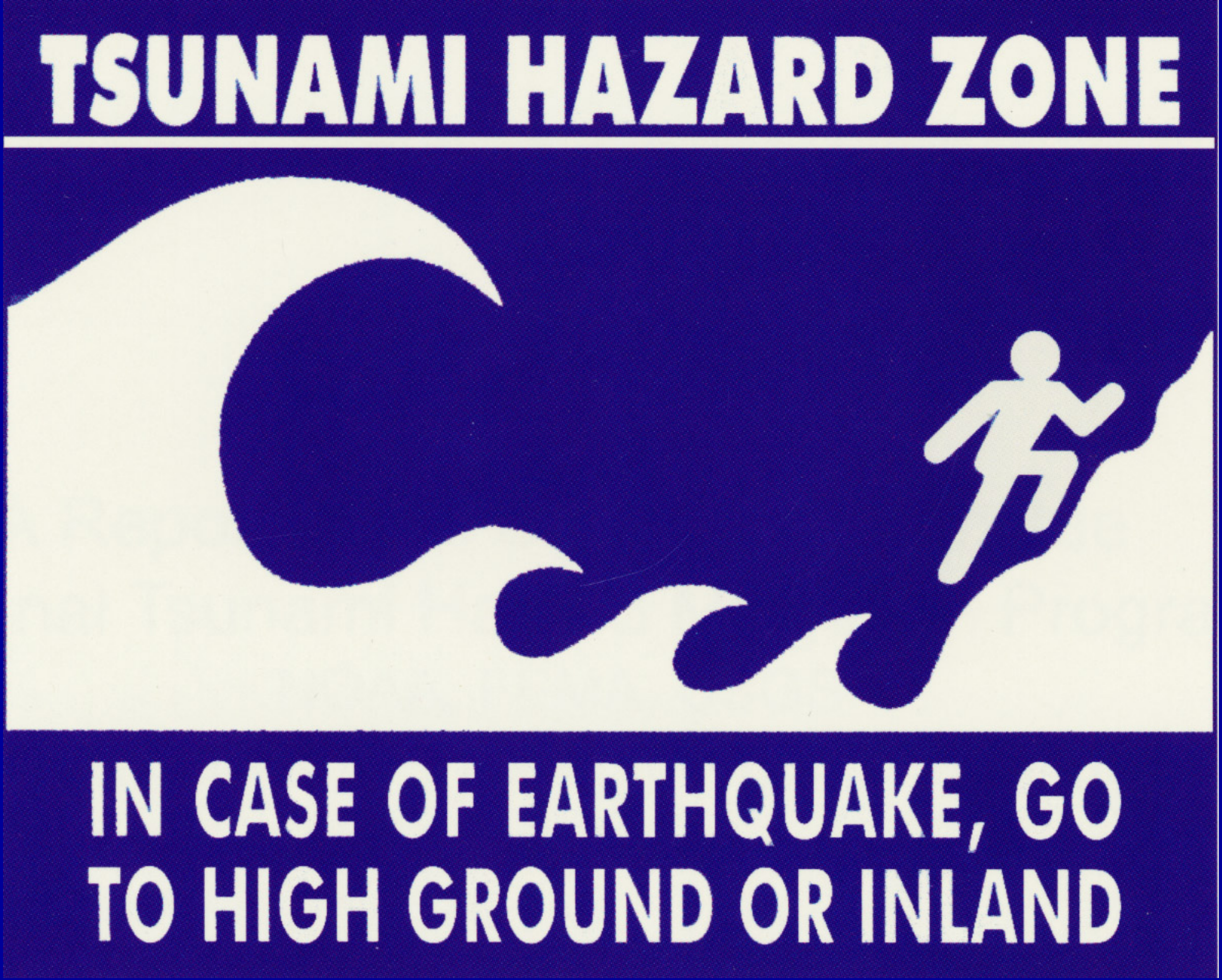
from Nobuo Shuto

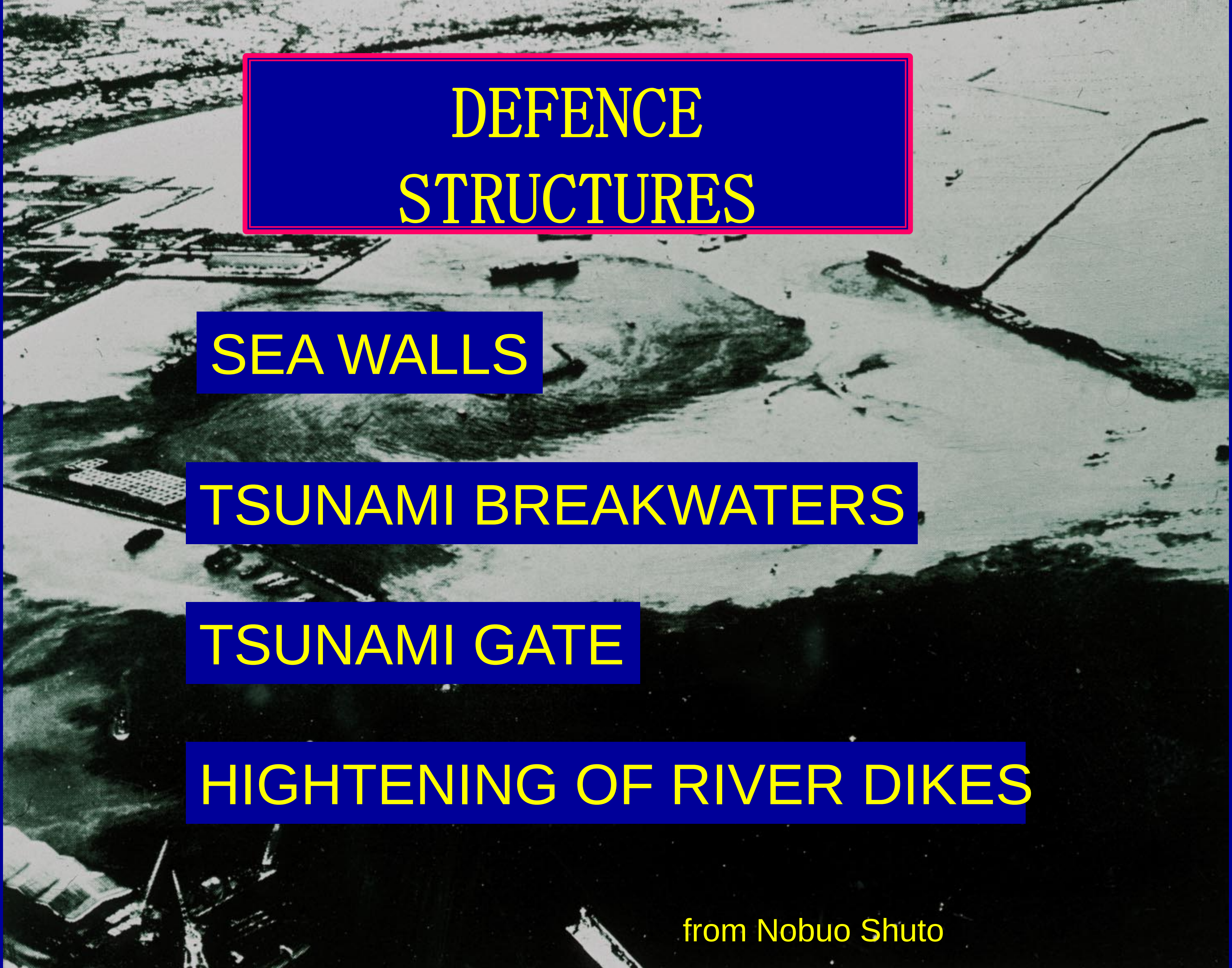
Storm surge trace

A TRAGEDY OF FOREIGN TOURIST WHO COULD NOT UNDERSTAND WARNING

Her last position

from Nobuo Shuto


TSUNAMI HAZARD ZONE
IN CASE OF EARTHQUAKE, GO TO HIGH GROUND OR INLAND

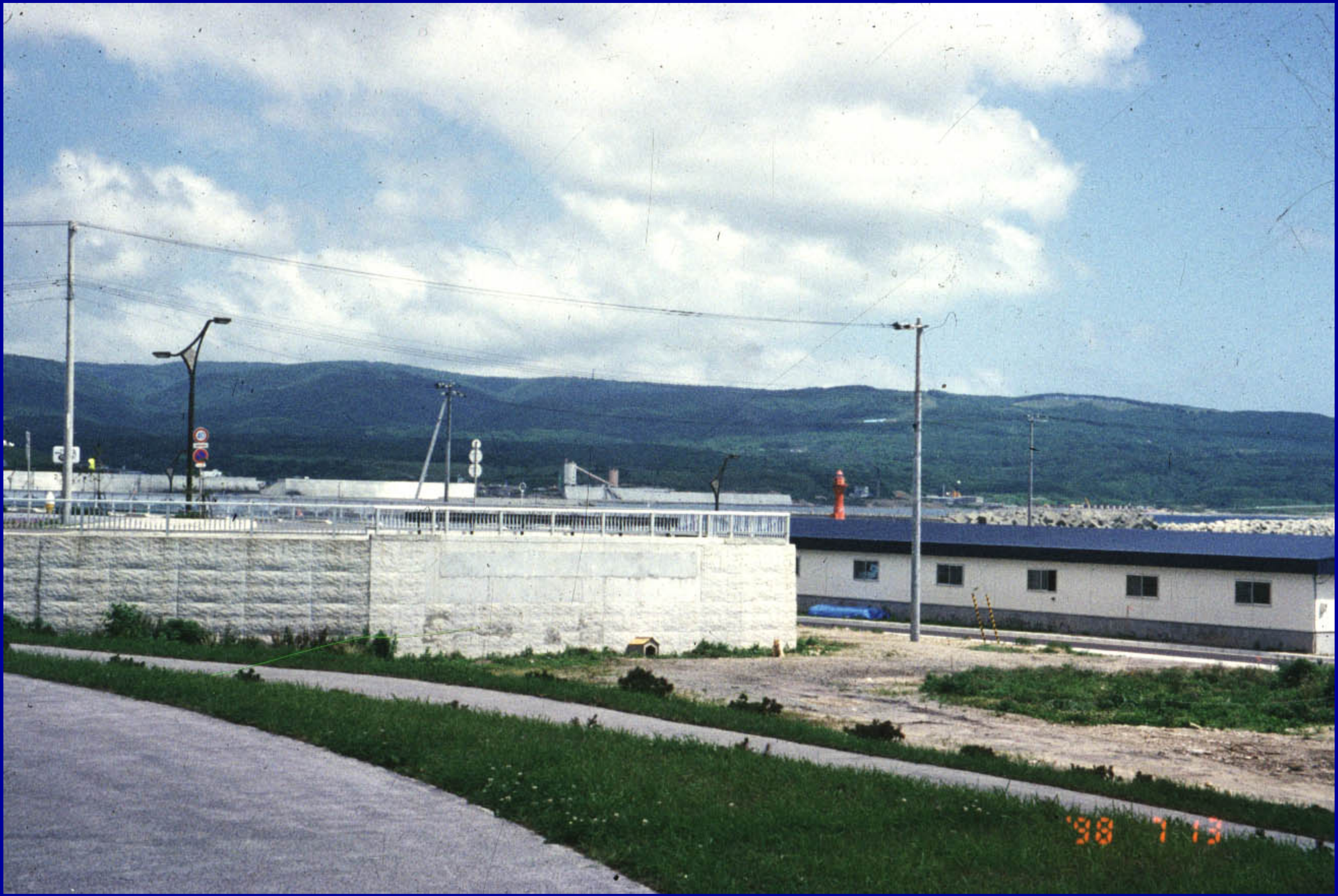


DEFENCE STRUCTURES

- SEA WALLS
- TSUNAMI BREAKWATERS
- TSUNAMI GATE
- HIGHTENING OF RIVER DIKES

from Nobuo Shuto

ARTIFICIALLY-ELEVATED GROUND

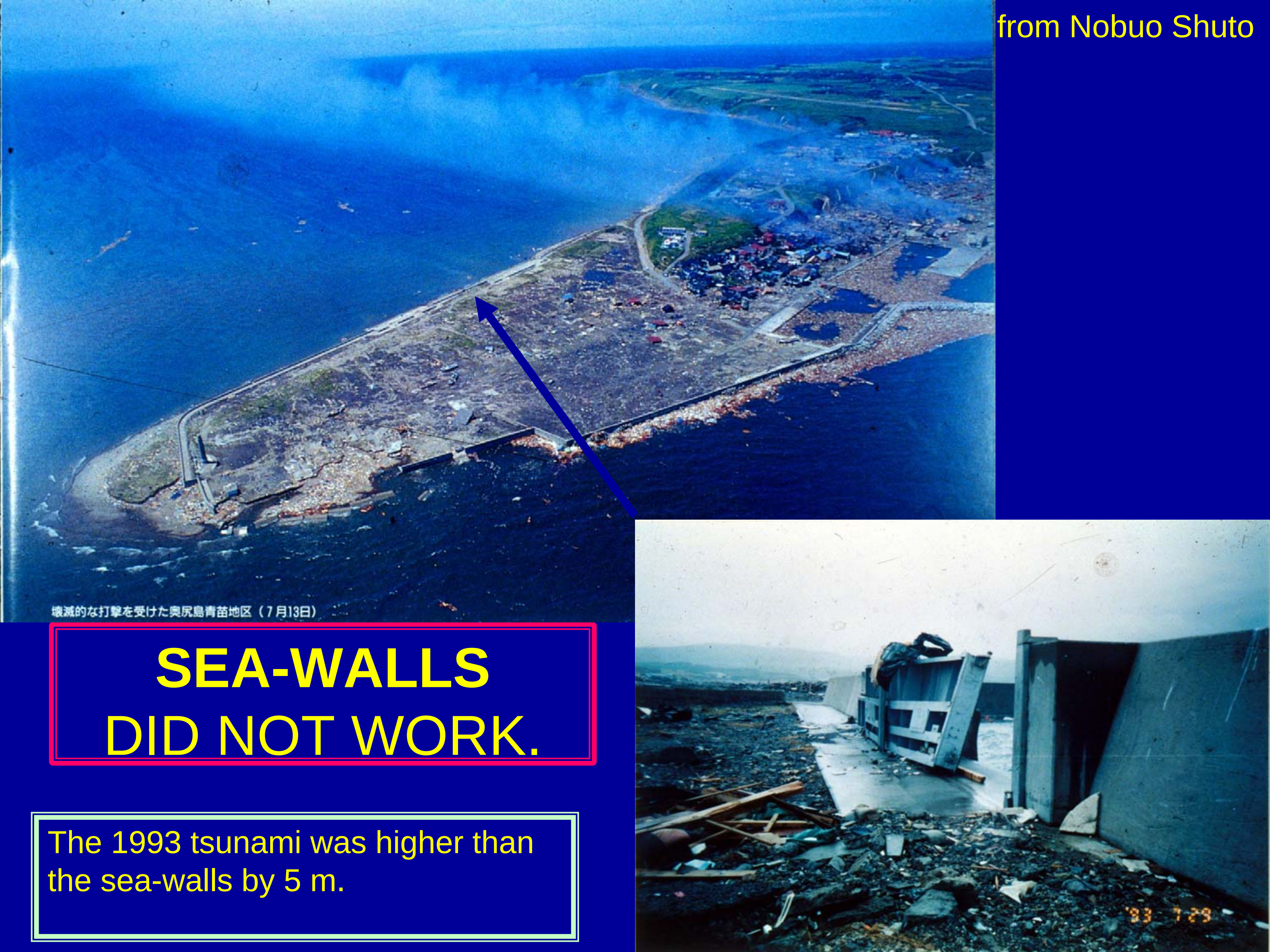


SEA-WALLS WORKED

The 1968 tsunami reflected by sea-walls.

from Nobuo Shuto

from Nobuo Shuto

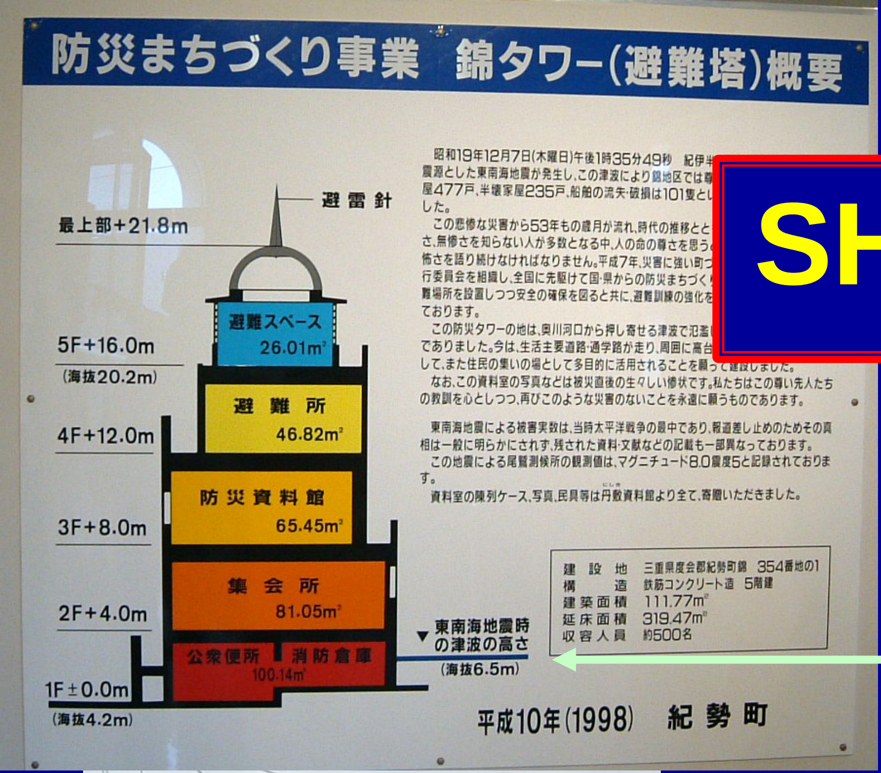


SEA-WALLS
DID NOT WORK.

The 1993 tsunami was higher than the sea-walls by 5 m.

from Nobuo Shuto

SHELTER TOWER



防災まちづくり事業　錦タワー(避難塔)概要

避雷針
最上部+21.8m
避難スペース 26.01m²
5F+16.0m
(海抜20.2m)
避難所 46.82m²
4F+12.0m
防災資料館 65.45m²
3F+8.0m
集会所 81.05m²
2F+4.0m
公衆便所　消防倉庫 100.14m²
1F±0.0m
(海抜4.2m)
▼東南海地震時の津波の高さ
(海抜6.5m)

昭和19年12月7日(木曜日)午後1時35分49秒　紀伊半
震源とした東南海地震が発生し、この津波により錦地区では
屋477戸、半壊家屋235戸、船舶の流失・破損は101隻とい
した。

この悲惨な災害から53年もの歳月が流れ、時代の推移とと
さ、無惨さを知らない人が多数となる中、人の命の尊さを思う
怖さを語り続けなければなりません。平成7年、災害に強い町づ
行委員会を組織し、全国に先駆けて国・県からの防災まちづく
難場所を設置しつつ安全の確保を図ると共に、避難訓練の強化を
ております。

この防災タワーの地は、奥川河口から押し寄せる津波で氾濫
でありました。今は、生活主要道路・通学路が走り、周囲に高台
して、また住民の集いの場として多目的に活用されることを願って建設しました。

なお、この資料室の写真などは被災直後の生々しい惨状です。私たちはこの尊い先人たちの教訓を心としつつ、再びこのような災害のないことを永遠に願うものであります。

東南海地震による被害実数は、当時太平洋戦争の最中であり、報道差し止めのためその真相は一般に明らかにされず、残された資料・文献などの記載も一部異なっております。

この地震による尾鷲測候所の観測値は、マグニチュード8.0震度5と記録されております。

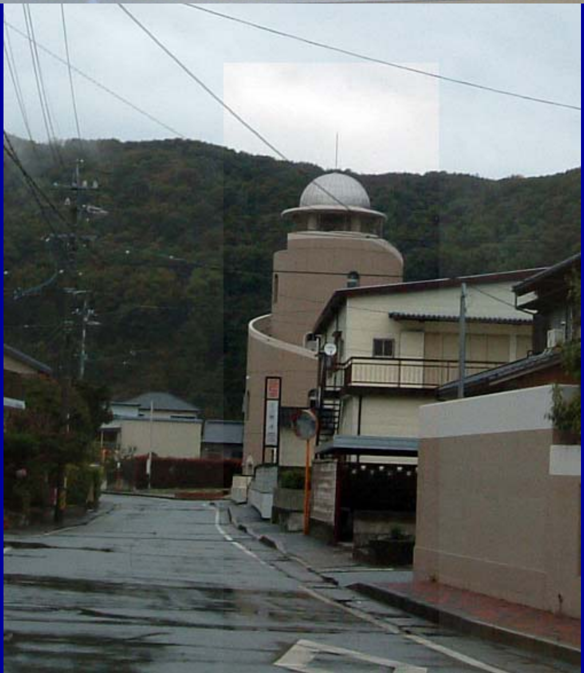
資料室の陳列ケース、写真、民具等は丹敷（にしき）資料館より全て寄贈いただきました。

建設地	三重県度会郡紀勢町錦　354番地の1
構造	鉄筋コンクリート造　5階建
建築面積	111.77m²
延床面積	319.47m²
収容人員	約500名

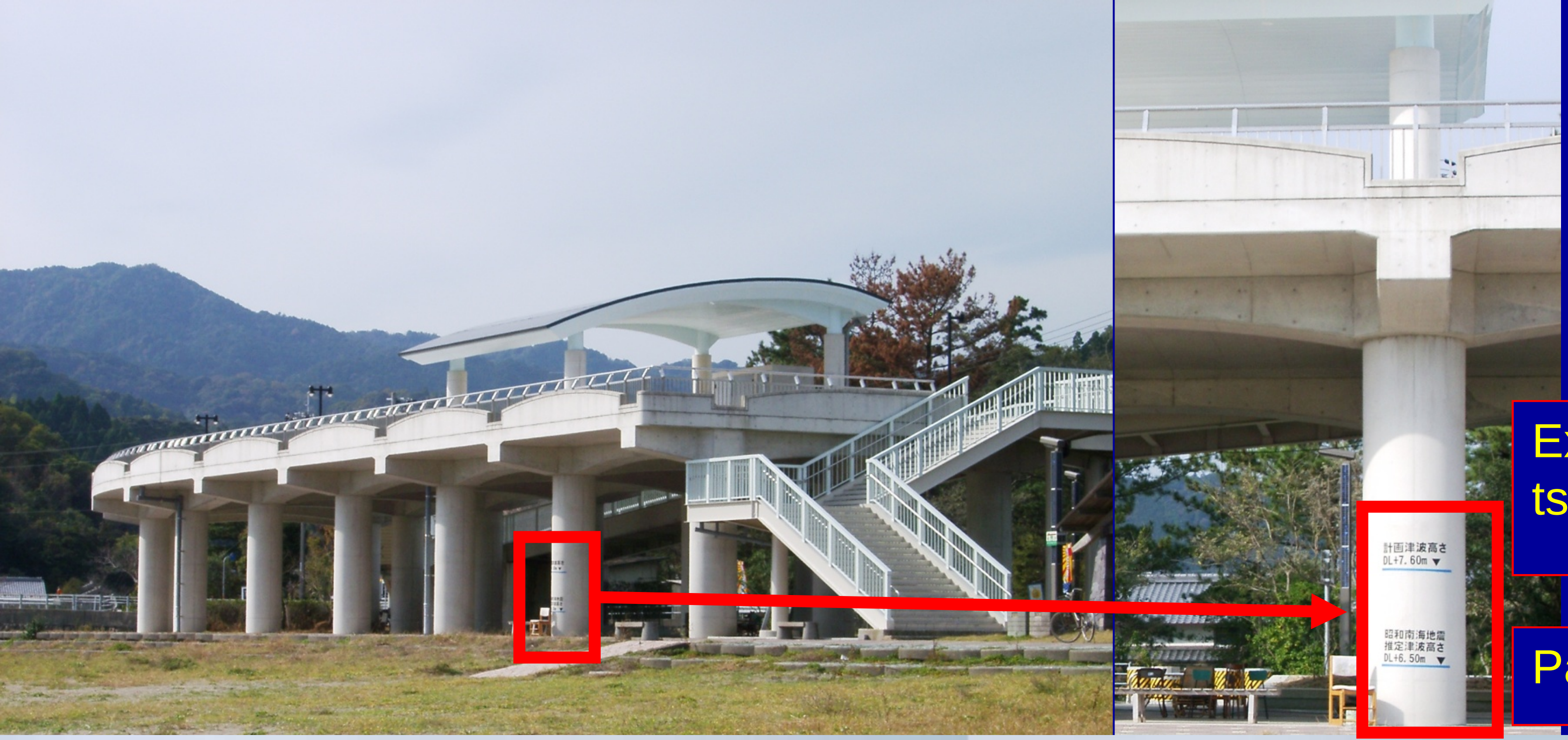
平成10年(1998)　紀勢町

4th & 5th: Shelter
3rd: Tsunami museum
2nd: Meeting room
1st: Ware house

Tsunami level

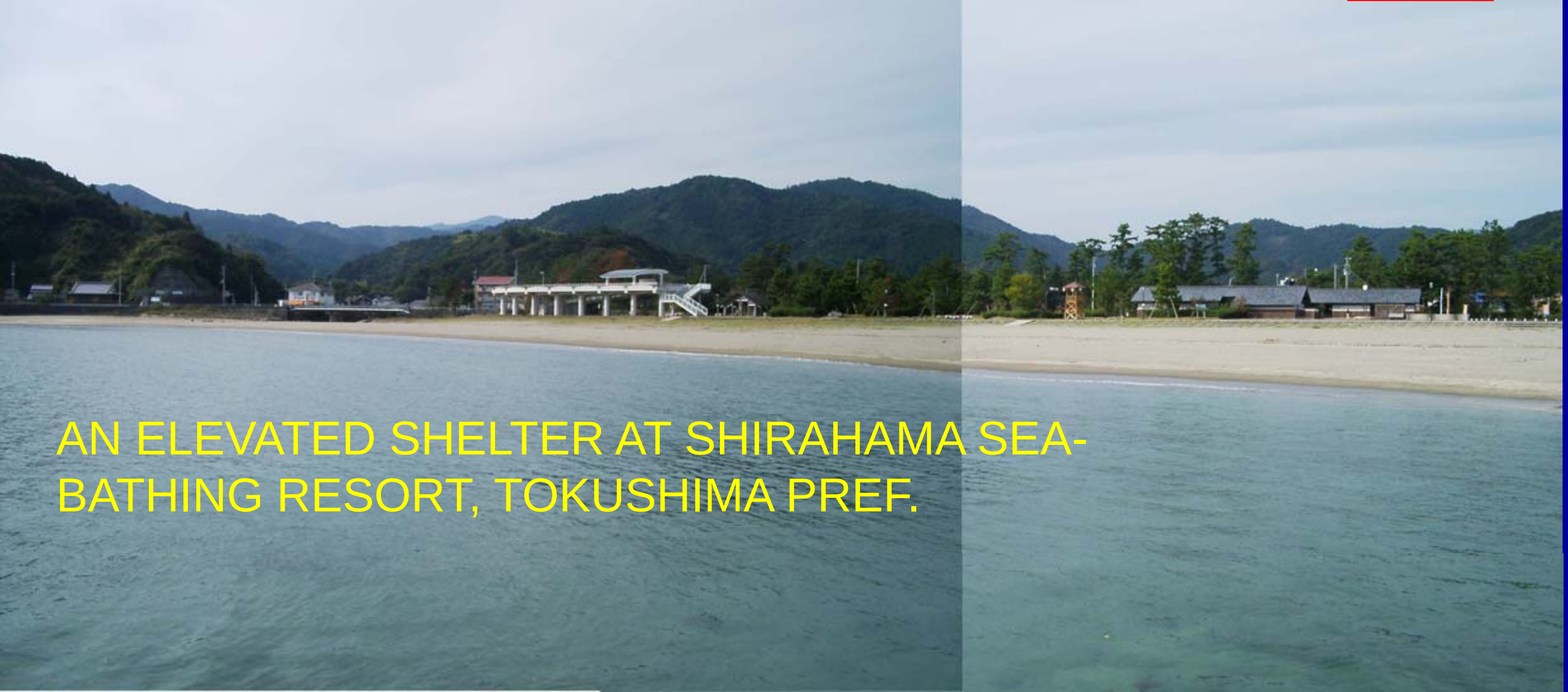


Wat Ban Nyan, Khao Lak



Expected tsunami

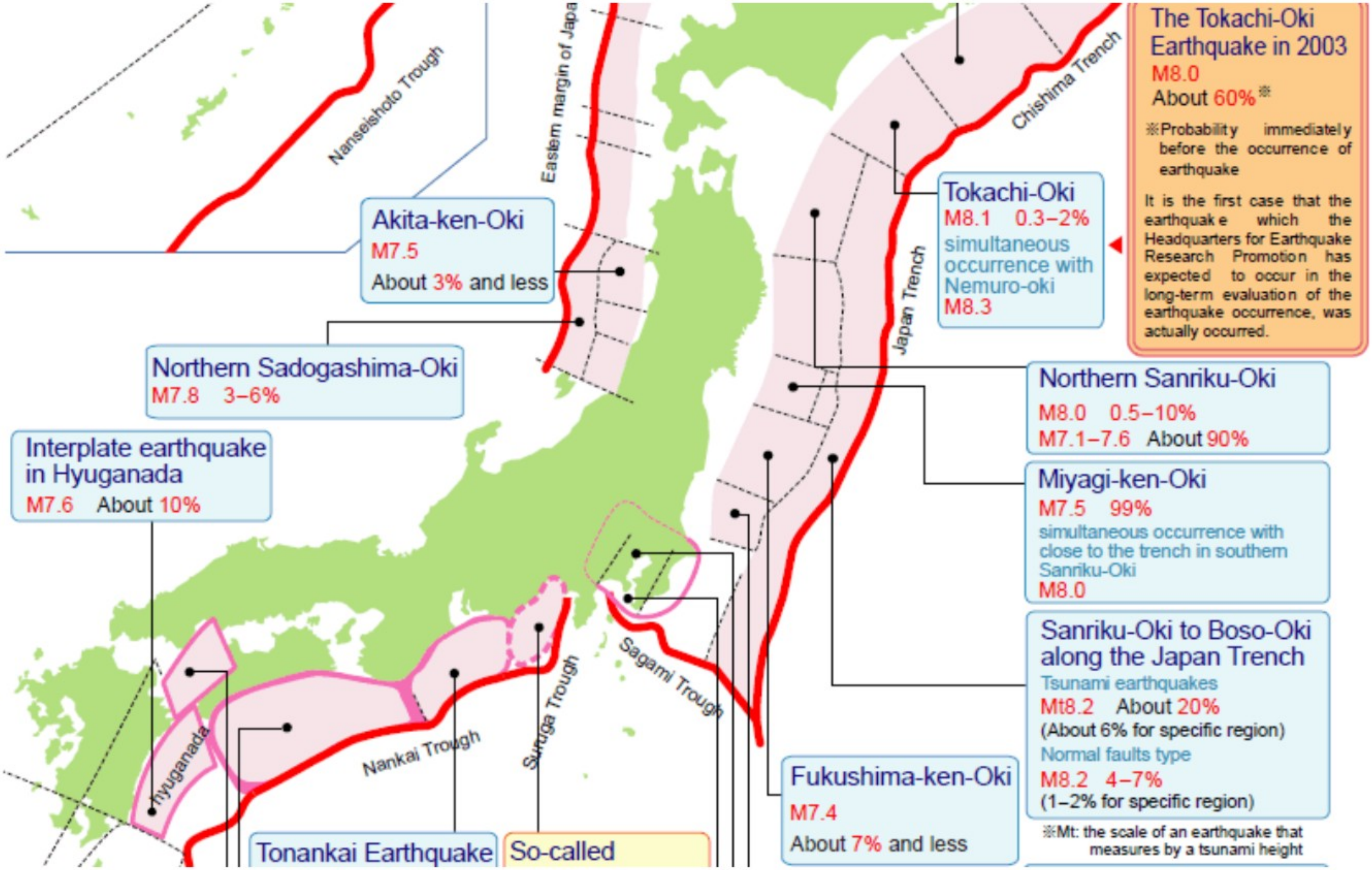
Past tsunami



AN ELEVATED SHELTER AT SHIRAHAMA SEA-BATHING RESORT, TOKUSHIMA PREF.

from
Nobuo
Shuto

HAZARD MAP January 2011



The Tokachi-Oki Earthquake in 2003
M8.0
About 60%※

※Probability immediately before the occurrence of earthquake

It is the first case that the earthquake which the Headquarters for Earthquake Research Promotion has expected to occur in the long-term evaluation of the earthquake occurrence, was actually occurred.

Tokachi-Oki
M8.1 0.3–2%
simultaneous occurrence with Nemuro-oki
M8.3

Akita-ken-Oki
M7.5
About 3% and less

Northern Sadogashima-Oki
M7.8 3–6%

Interplate earthquake in Hyuganada
M7.6 About 10%

Northern Sanriku-Oki
M8.0 0.5–10%
M7.1–7.6 About 90%

Miyagi-ken-Oki
M7.5 99%
simultaneous occurrence with close to the trench in southern Sanriku-Oki
M8.0

Sanriku-Oki to Boso-Oki along the Japan Trench
Tsunami earthquakes
Mt8.2 About 20%
(About 6% for specific region)
Normal faults type
M8.2 4–7%
(1–2% for specific region)

※Mt: the scale of an earthquake that measures by a tsunami height

Fukushima-ken-Oki
M7.4
About 7% and less

Tonankai Earthquake

So-called

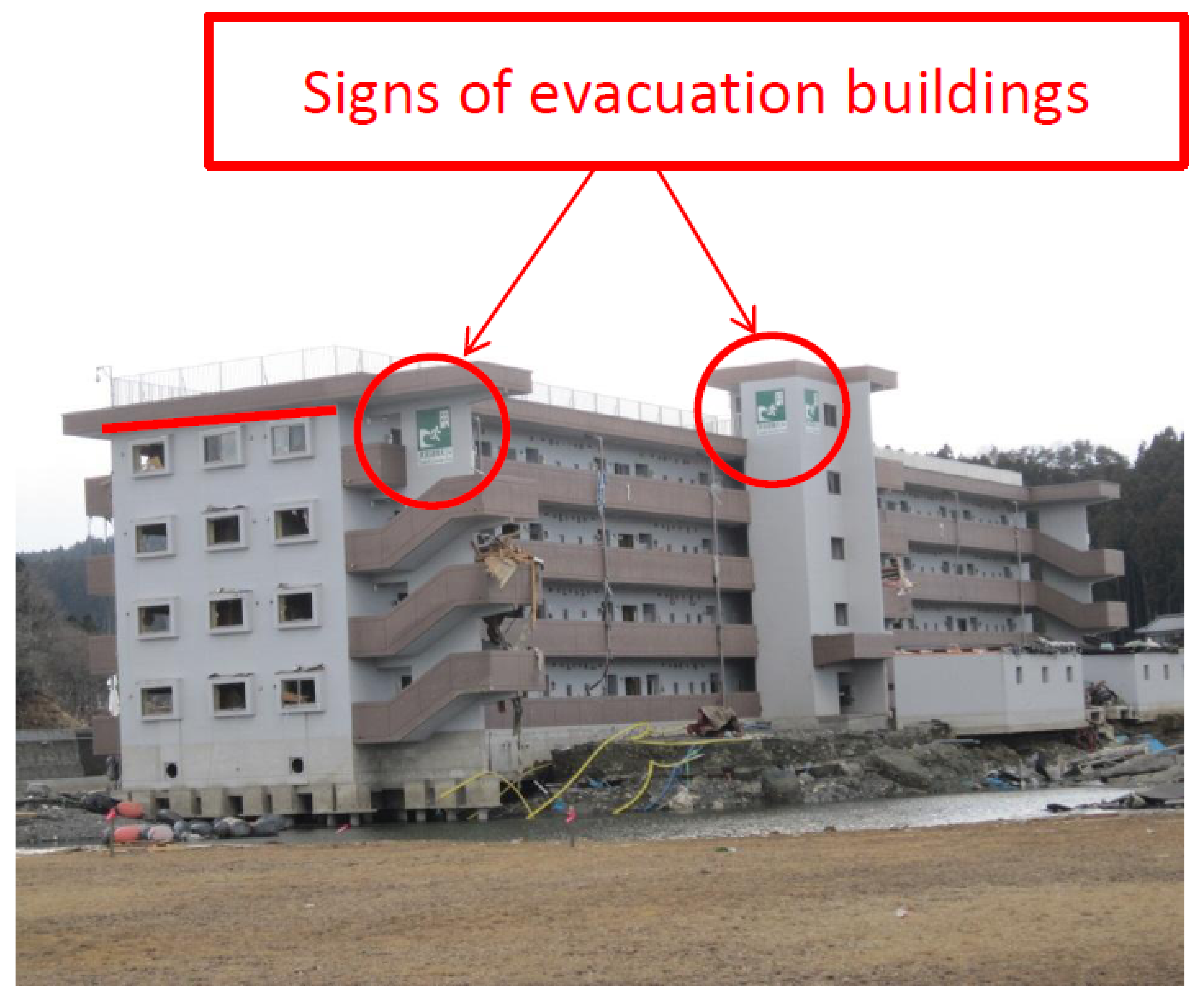
http://www.jishin.go.jp/main/img/w_shokai-e_kaiko.gif

Tsunami Catalogue for the Sanriku District near the Sendai Area, mostly based upon Miyagi Showa Shinsho-Shi (Record of the Showa Earthquake and Tsunami in Miyagi Prefecture) and partially on Shuto’s memory.

869

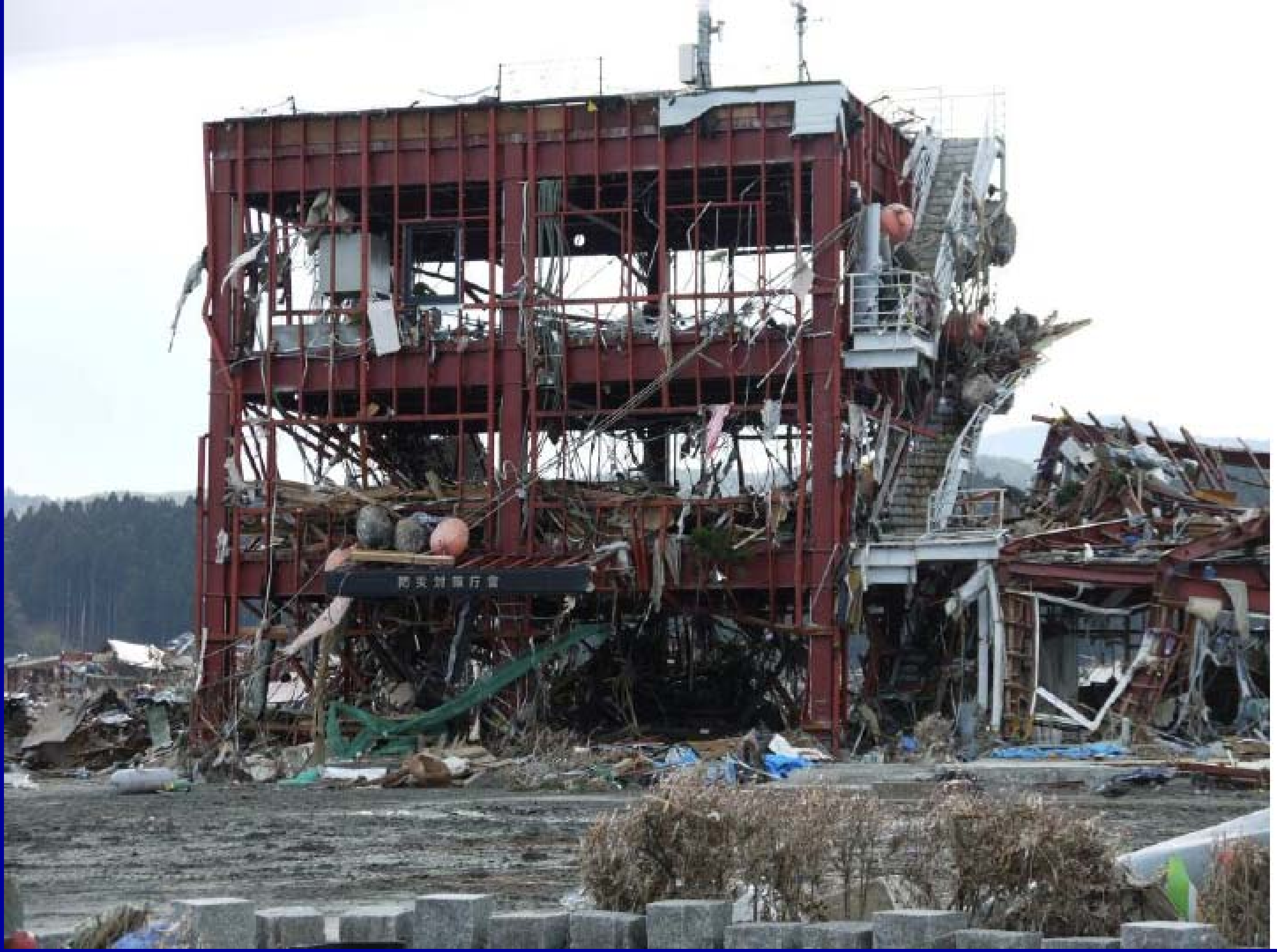
Giant earthquake in the Tohoku District. Tsunami flooded up to the Tagajo castle near Sendai. Over 1,000 drowned.

At Minami-Sanriku town, an apartment building was situated right next to the coast and designated as an evacuation building as shown by evacuation signs, but there were traces that tsunami also had reached the 4th floor.



Signs of evacuation buildings

This three-story building (below) was the disaster management center of the town which was also designed to function as a tsunami evacuation building. At the time of tsunami, about thirty municipal officials evacuated to the rooftop but only ten of them survived. A young female official who kept delivering evacuation message to the villagers until the last moment has not been found yet.



Civilization exists by geological consent—

subject to change without notice

Will Durant